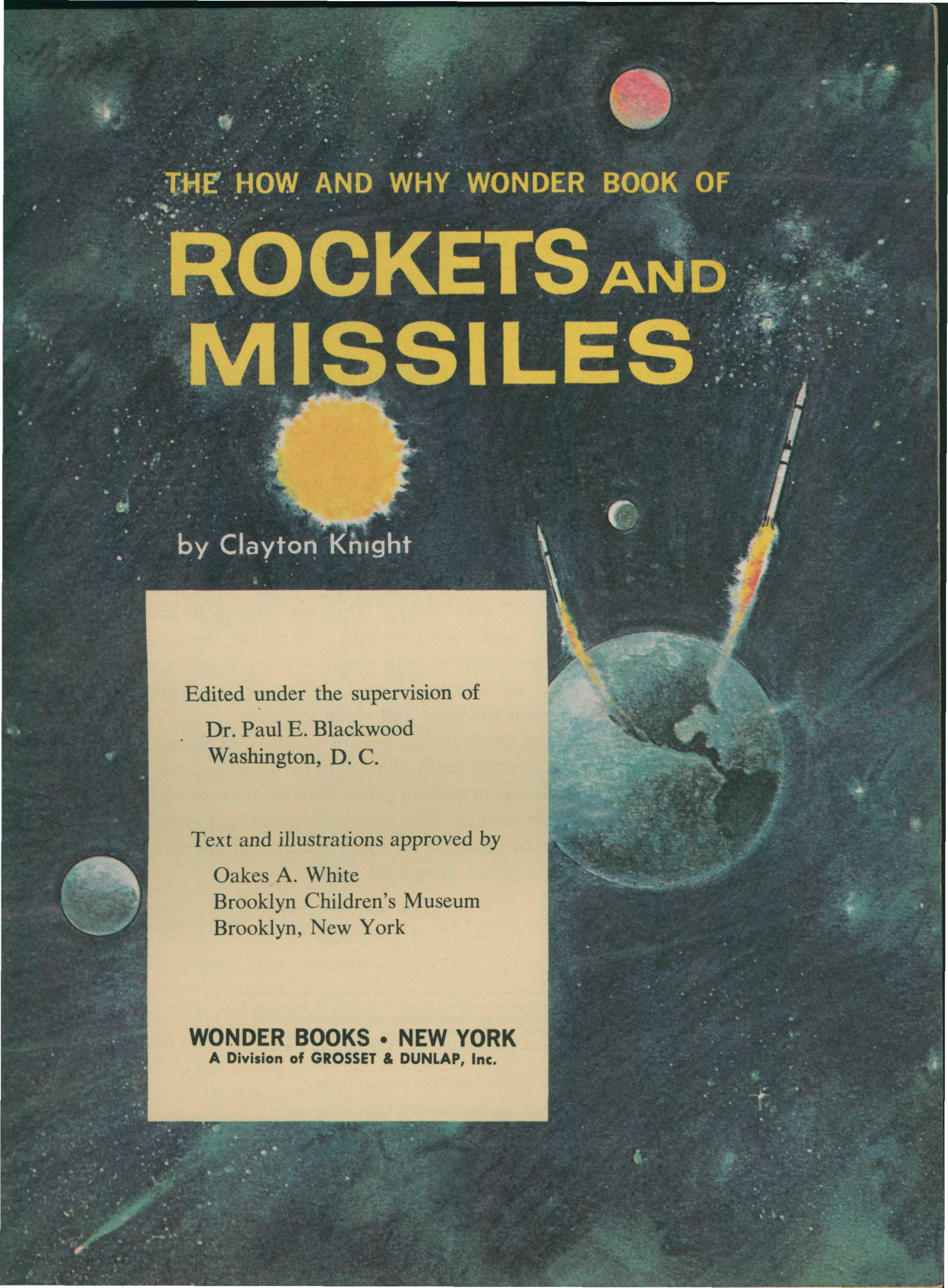
The HOW AND WHY Wonder Book of

ROCKETS AND MISSILES



THE HOW AND WHY WONDER BOOK OF

ROCKETS AND MISSILES

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INTRODUCTION

This book is one in a series of *How and Why Wonder Books* for young readers dealing with subjects of current interest in science and technology. Through authentic text and illustrations, it presents brief answers to several dozen important questions about rockets and missiles.

It reminds us that man's knowledge about the universe is vast. Yet new and exciting developments are announced every day, evidence that science is moving ahead at a remarkable pace. We know that there is still much more to be learned. Scientists throughout the world are seeking relentlessly for a new and better understanding about things in nature, ranging in their search from the tiniest atom to the limits of outer space. And as the answers to "how" and "why" questions are found, they provide further interesting knowledge that is useful for controlling our environment.

Children also ask "How?" and "Why?" They are curious to learn more and more about the world. And parents — to satisfy their own interest and to stimulate and keep up with youth — must be informed about modern advances of science as well. Fortunately, through books, parents and children can read and study together.

Learning the *how's* and *why's* in one field of scientific exploration usually leads to interest in other fields. This is to the good because it is important for young people in making career choices to know about the many opportunities in science. This book on rockets and missiles is one which will open new horizons for every reader and encourage further reading and exploration in related fields.

Paul E. Blackwood

Dr. Blackwood is a professional employee in the U. S. Office of Education. This book was edited by him in his private capacity and no official support or endorsement by the Office of Education is intended or should be inferred.

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HOW OLD IS THE ROCKET PRINCIPLE?

HISTORICAL records show that as early as 800 years before Christ, the Chinese — who were the first to discover gunpowder — were shooting powder-packed tubes on a stick into the air to amuse their people.

These rockets followed all three of Sir Isaac Newton's three laws of motion. Mainly, however, it was Newton's third law which was in effect: For every *action,* there is an equal and opposite *reaction.* Thus, when the rocket's burning gases thrust *downward,* the opposite reaction is a thrust *upward,* sending the rocket in a fiery arc into the night sky.

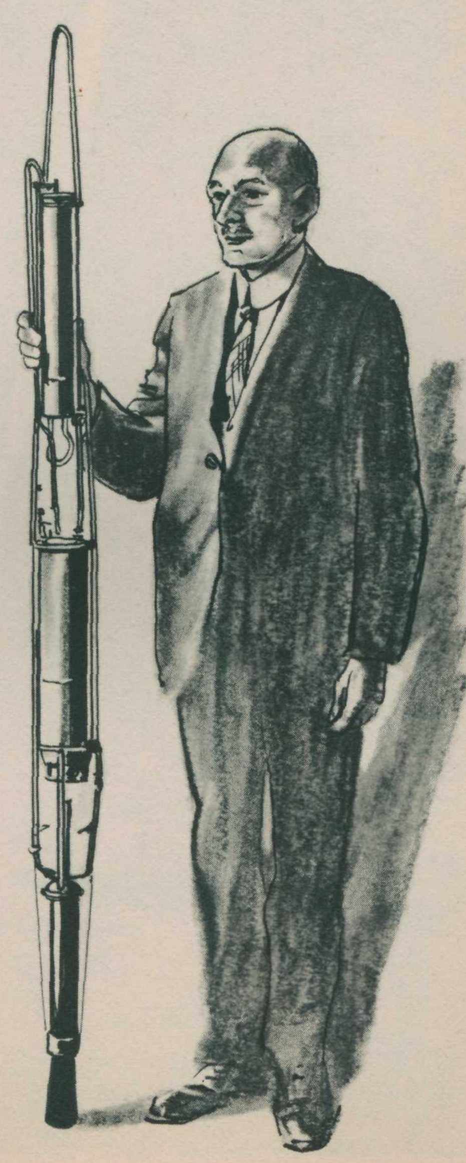
In the 1700's William Congreve, in England, tested improved Chinese rockets as weapons of war. They achieved little success at the time, although when Francis Scott Key wrote the *Star Spangled Banner* during the War of 1812, the phrase, "the rockets' red glare" referred to Congreve missiles fired by the British against Fort McHenry.

The real father of modern rocketry was the American, Dr. Robert Goddard, a physics professor who, in the early 1900's, began experiments with rockets to send weather-recording instruments higher than meteorological balloons had ever gone.

He tried both solid fuel (powder) and liquid fuel (gasoline and oxygen), and in 1926 the world's first liquid-propelled rocket was successfully fired at Auburn, Massachusetts.

Starting with his first crude apparatus, he went on to add guidance features, an automatic parachute to bring recording instruments back to earth safely, and subsequently developed the principle of the multi-stage rocket which, forty years later, was used to put both United States and Russian spacecraft into orbit around the earth.

Goddard's first rocket



WHEN WERE ROCKETS FIRST USED IN MODERN WARFARE?

THE FORMER dictator of Germany, Adolph Hitler, boasted he would win World War II with his "secret weapons." In the summer of 1944, unusual launching sites were observed along the Belgian and Dutch coasts by British airmen.

Soon after, these weapons — giant German V-2 rockets — began hurtling across the English channel into London, the capital of England.

This ushered in an age of long-distance rocket-powered missiles that could carry nuclear warheads.

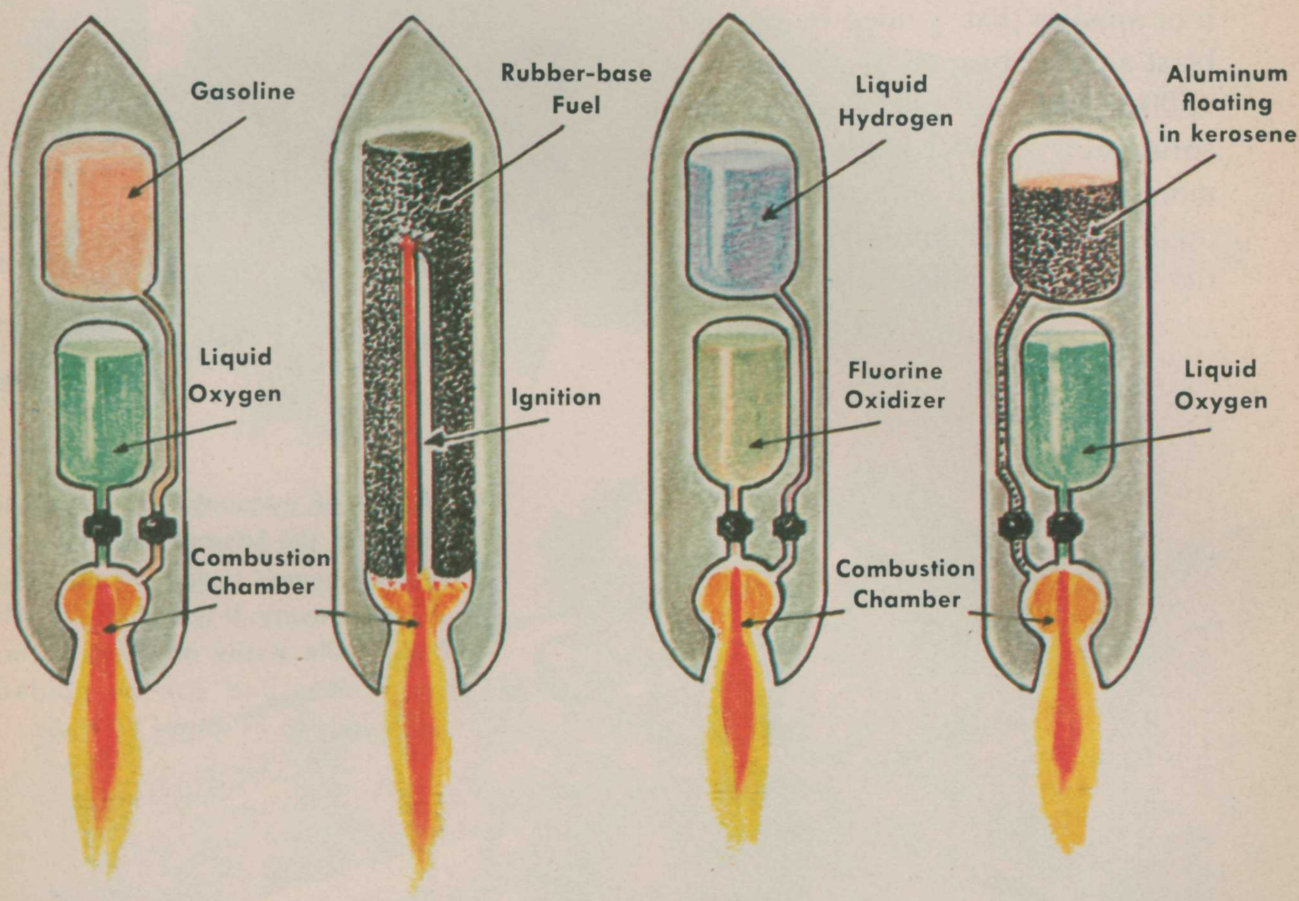
A V-2 LAUNCHING

WHAT ARE THE DIFFERENT KINDS OF ROCKET FUELS?

THE only engine capable of operating in airless space is the rocket which needs no outside air for combustion. In place of atmosphere, the rocket must have an oxidizer to make the fuel burn — usually liquid oxygen, which must be kept at 272 degrees below zero, F., and must be handled carefully.

Rockets burning solid fuels demand less care, but the fuel combustion is more difficult to control.

The first rocket engines had moderate thrust — the one in the X-1 delivered 6,000 pounds — but the *Apollo 8* astronauts began their moon journey on a Saturn 5 rocket which has a 7½-million-pound thrust! Nuclear rockets will be even more powerful.



LIQUID FUEL

Specific Thrust: 264.
The liquid fuel flow is easy to control. The rocket design is complicated, and mechanical failures are apt to occur.

SOLID FUEL

Specific Thrust: Above 250.
Solid fuel is easily stored and handled, but fuel combustion is hard to control.

EXOTIC FUEL

Specific Thrust: 373.
Exotic fuel gives the rocket greater speed and larger load-carrying capacity, but is difficult to store and handle.

METAL FUEL

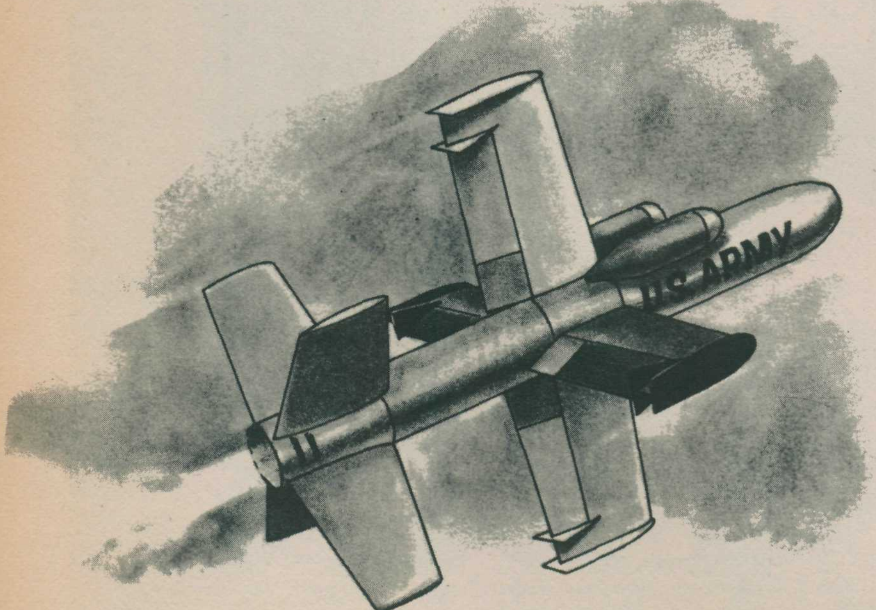
Specific Thrust: 325.
It is easily made and stored, but metal fuel is apt to clog pipelines. It is also hard to keep aluminum in suspension.

HOW DOES THE MODERN ARMY USE ROCKETS?

TO BE ready for battle under atomic war conditions, the modern army must have massive striking firepower that can be moved to the threatened areas with great rapidity.

The U. S. Army has developed a whole family of solid-fueled rockets mounted on mobile-launchers which have taken the place and exceeded the firepower of conventional artillery. Their range varies from rockets which can stop a tank at 2,000 yards, to 27-foot missiles that, guided by radio, can blast a target twenty miles away with a 1500-pound warhead. Because of the solid fuel, Army rocket missiles are more nearly trouble-free than those using liquid propellant and are easier for the crews to handle.

LACROSSE • Mounted on a mobile-launcher, the Lacrosse can hit and destroy enemy strong points up to 20 miles away. It is a solid-propellant missile easily handled by infantrymen, and can be guided accurately to its target by radio.



DART • This small but effective anti-tank rocket, with a range of over 2,000 yards, is used by infantry and armored combat units.

The change-over from the early days of horse-drawn guns used in World War I to the mechanized artillery of World War II is now being carried forward by the re-equipment of our modern armies with rocket missiles.

Not only are the short-range missiles more accurate and much more destructive, but rocket propulsion has extended the range of weapons far beyond that reached by old-time cannon.

LITTLE JOHN • Little John is a 12-foot Army missile fired from a small mobile launcher. It can be guided 20 miles to a target.

HONEST JOHN • Honest John is a 3-ton, 27-foot, solid-propellant missile with a range of about 30 miles.

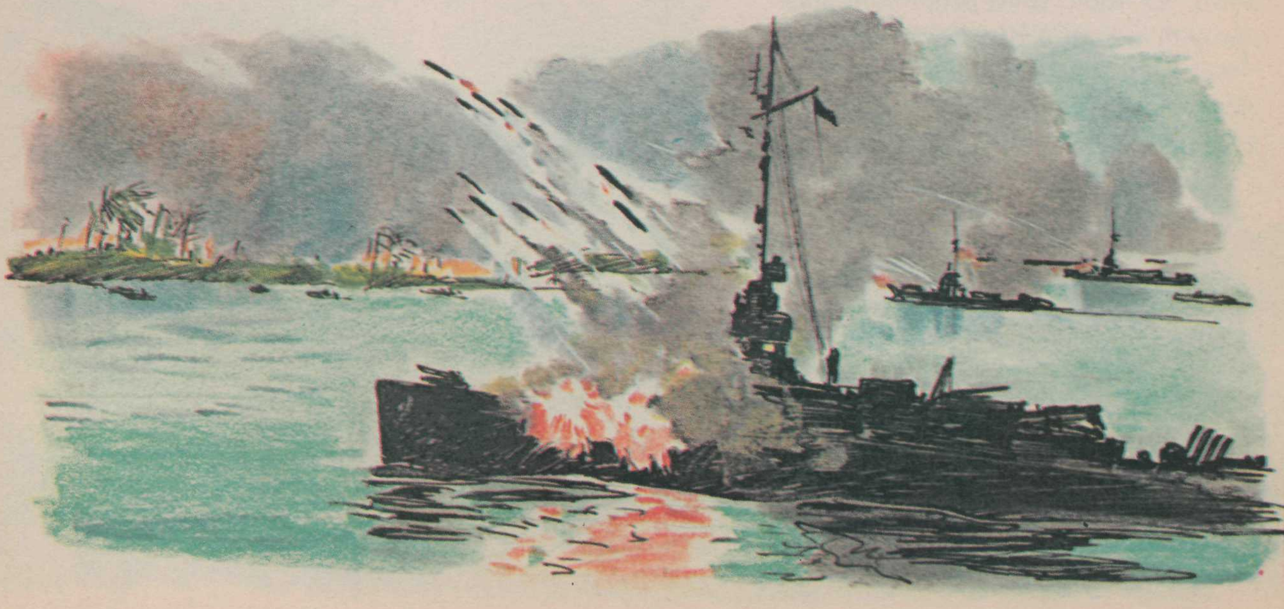
WERE MANY ROCKETS FIRED IN WORLD WAR II?

ALTHOUGH the Germans had built and fired huge rocket missiles into England, they spent little time or effort on smaller artillery-type rockets.

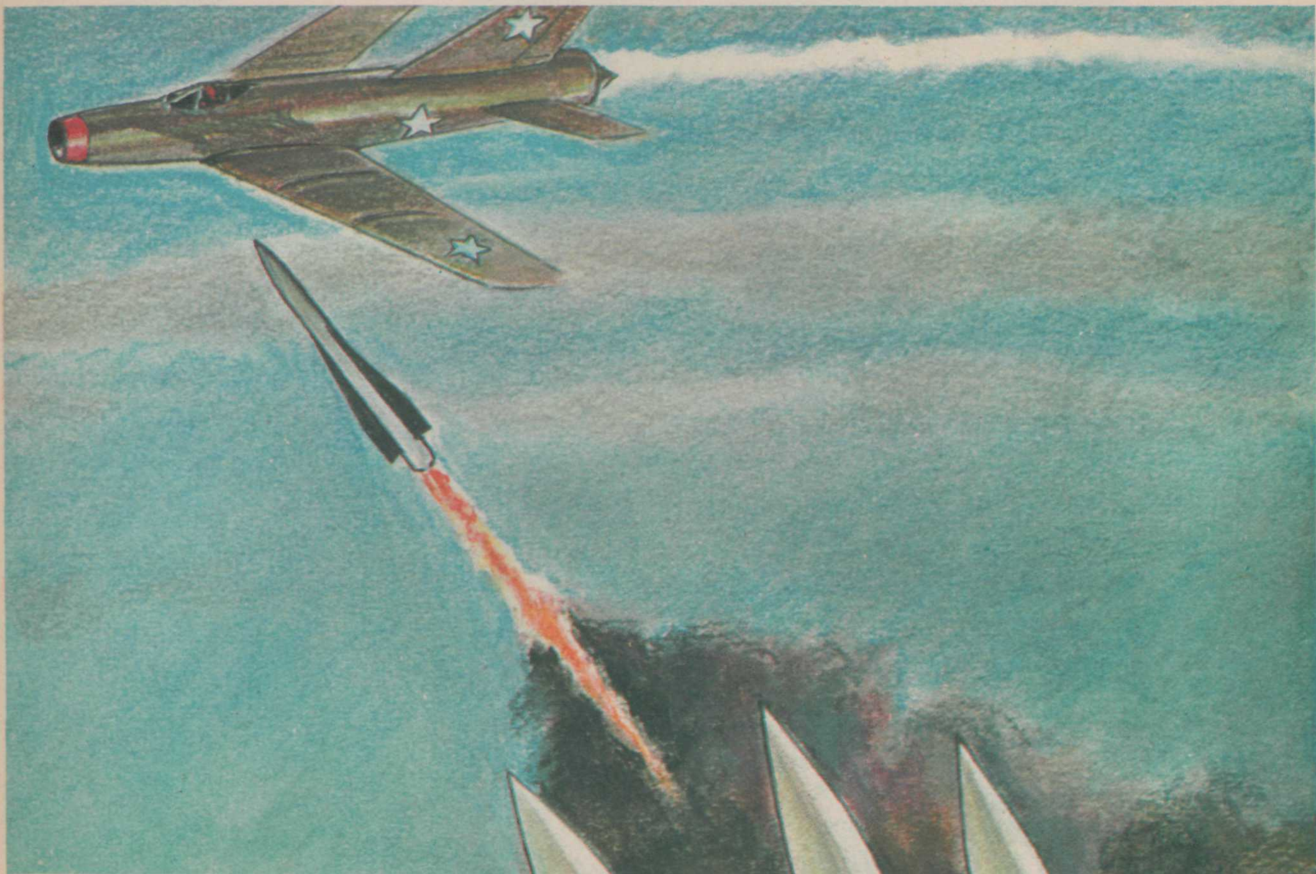
However, the Russians, invaded by Germany and desperate for increased firepower, perfected several effective types of rocket batteries. They were almost the only nation fighting in World War II to use rockets on land.

The United States Navy was also quick to test the value of rockets and first used them in the invasion of North Africa in 1942 to give support to landing craft storming the beaches.

Later, in the island battles of the Pacific, when U. S. Marines had gone ashore and the big guns and the air bombing had ceased, it was the rockets that gave support to the land forces.



IS THE ROCKET MISSILE REPLACING ARTILLERY?



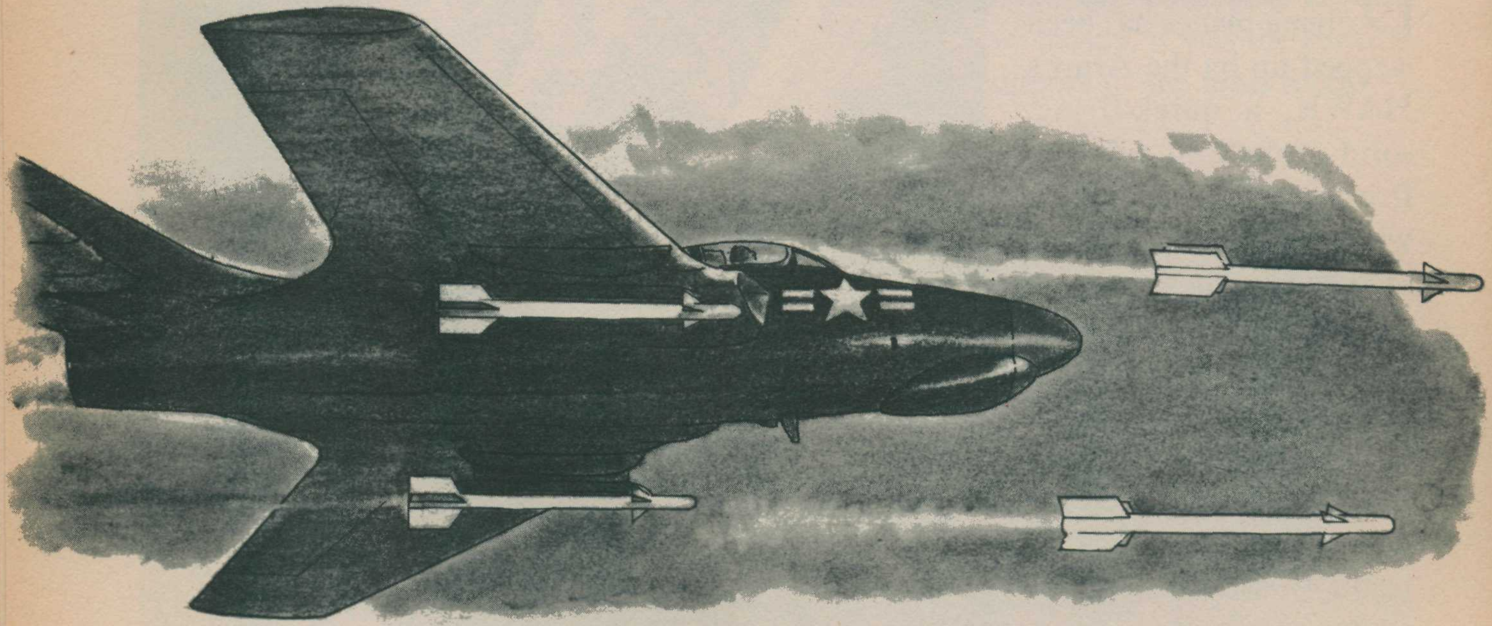

DEFENSE against low-flying planes has been stepped up by the Army's HAWK, a quick-firing, solid-propellant missile. It can be fired easily anywhere in the field from a mobile launcher or from small aircraft and helicopters. A sister weapon to the high-altitude Nike ZEUS and Nike SPRINT, it is directed by low-altitude radar which can respond instantly to the swiftest enemy plan's attempts to escape.

WHAT TYPES OF ROCKETS ARE SHOT FROM PLANES?

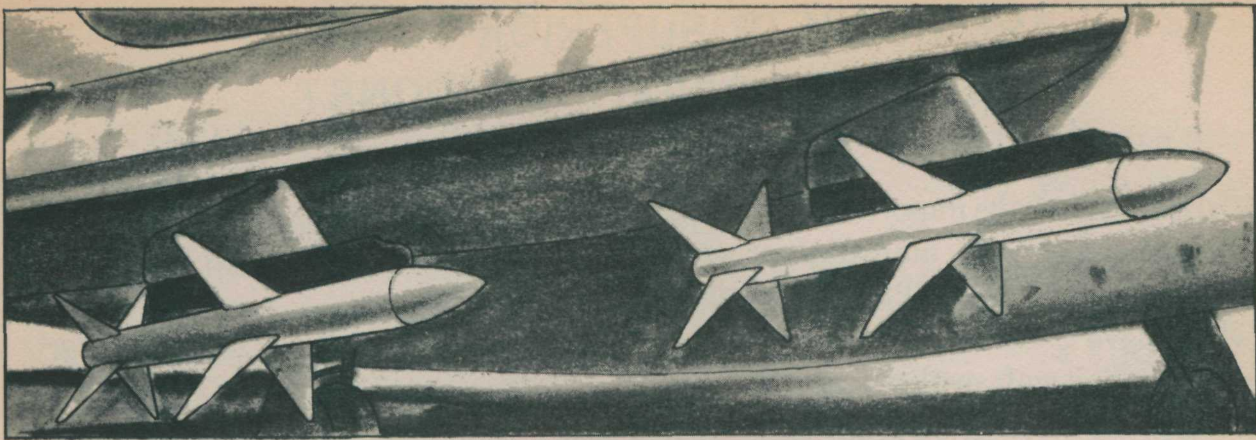
WHEN jet planes began flying at twice the speed of sound, there was insistent need for faster-firing and more destructive weapons.

In contrast to the 50-caliber bullet or the cannon shell, the rocket with its incredible velocity and destructive power was a partial answer to the problem. The electronic brain that is built into a rocket can easily outwit bombers and fighter aircraft trying to escape it. Thus the rocket is regarded as a perfect airborne weapon.

The FALCON, a 6½-foot, 112-pound rocket, can outmaneuver and destroy aircraft at any altitude.

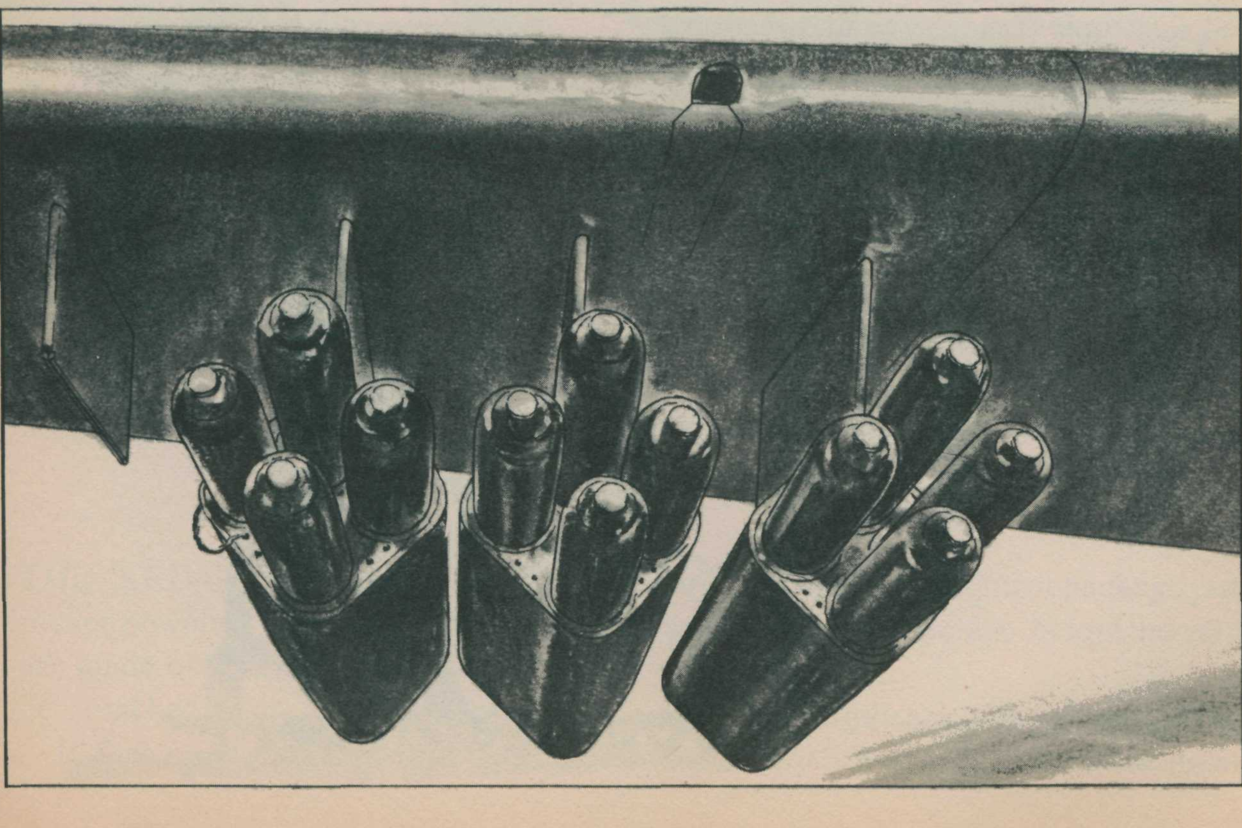


The SIDEWINDER, a solid-propellant rocket, is named after a fast and deadly rattlesnake. This rocket strikes fast and is infrared-guided to its target.



The SPARROW III is a 12-foot rocket which rides a radar beam to the target. Used by both the U.S Navy and the Marine Corps, it attains a speed of more than 1,500 mph within seconds after being fired from its fitting beneath a supersonic plane.

The ZUNI, a slim solid-propellant rocket whose guidance fins are folded until the rocket is launched from its carrier, can be fired singly or in salvos at supersonic speeds.



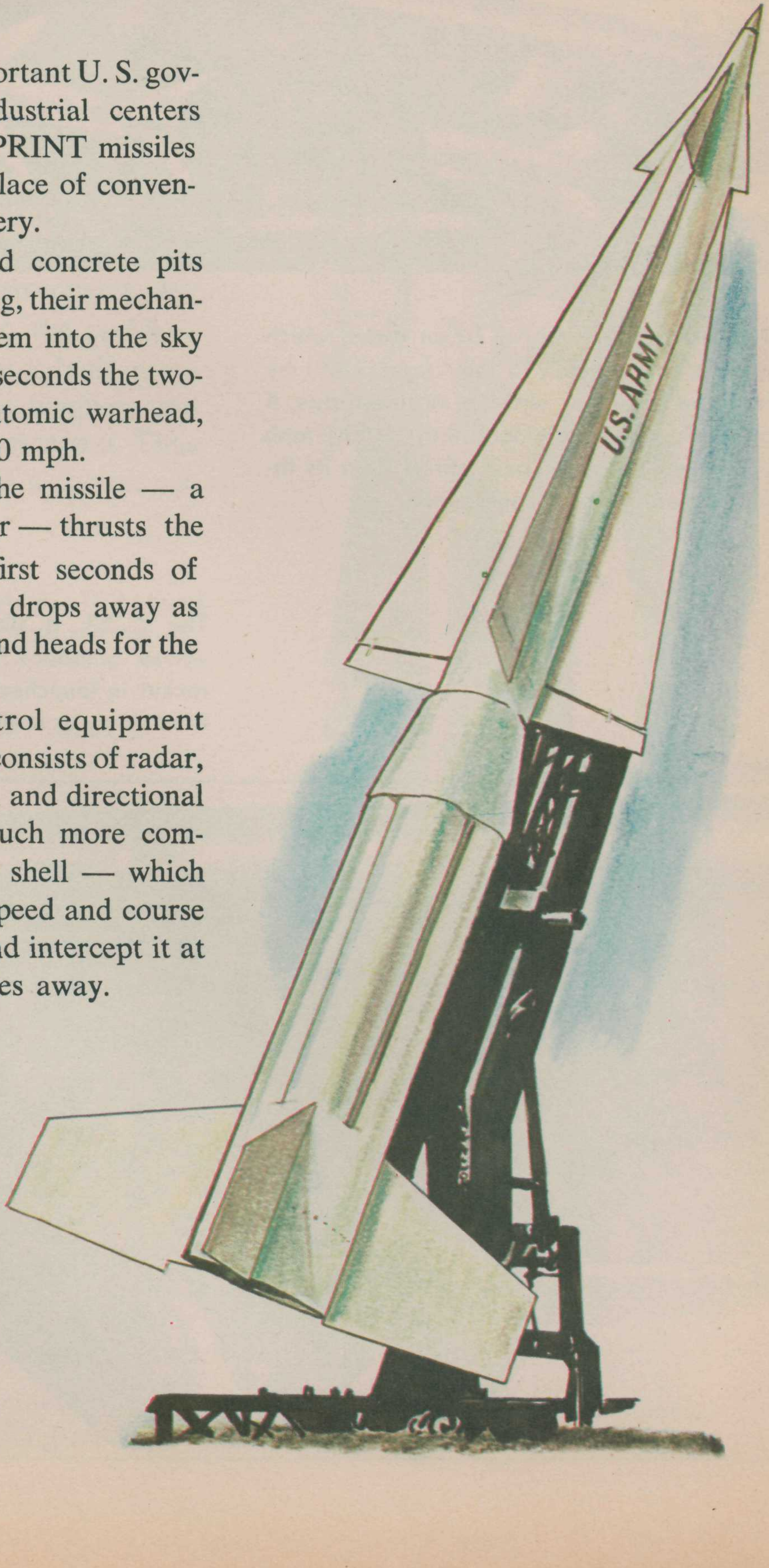
ARE ROCKETS SUPERIOR TO GUNS AS ANTIAIRCRAFT WEAPONS?

RINGING all the important U. S. governmental and industrial centers are batteries of Nike SPRINT missiles which have taken the place of conventional antiaircraft artillery.

Kept in underground concrete pits until the moment of firing, their mechanical launchers point them into the sky and within a matter of seconds the two-stage rocket, with an atomic warhead, can speed aloft at 2,200 mph.

The first stage of the missile — a solid-propellant booster — thrusts the SPRINT through its first seconds of vertical flight and then drops away as the second stage turns and heads for the target.

The elaborate control equipment within its second stage consists of radar, an electronic computer, and directional guidance systems — much more complex than any artillery shell — which take into account the speed and course of an enemy aircraft and intercept it at distances up to 75 miles away.

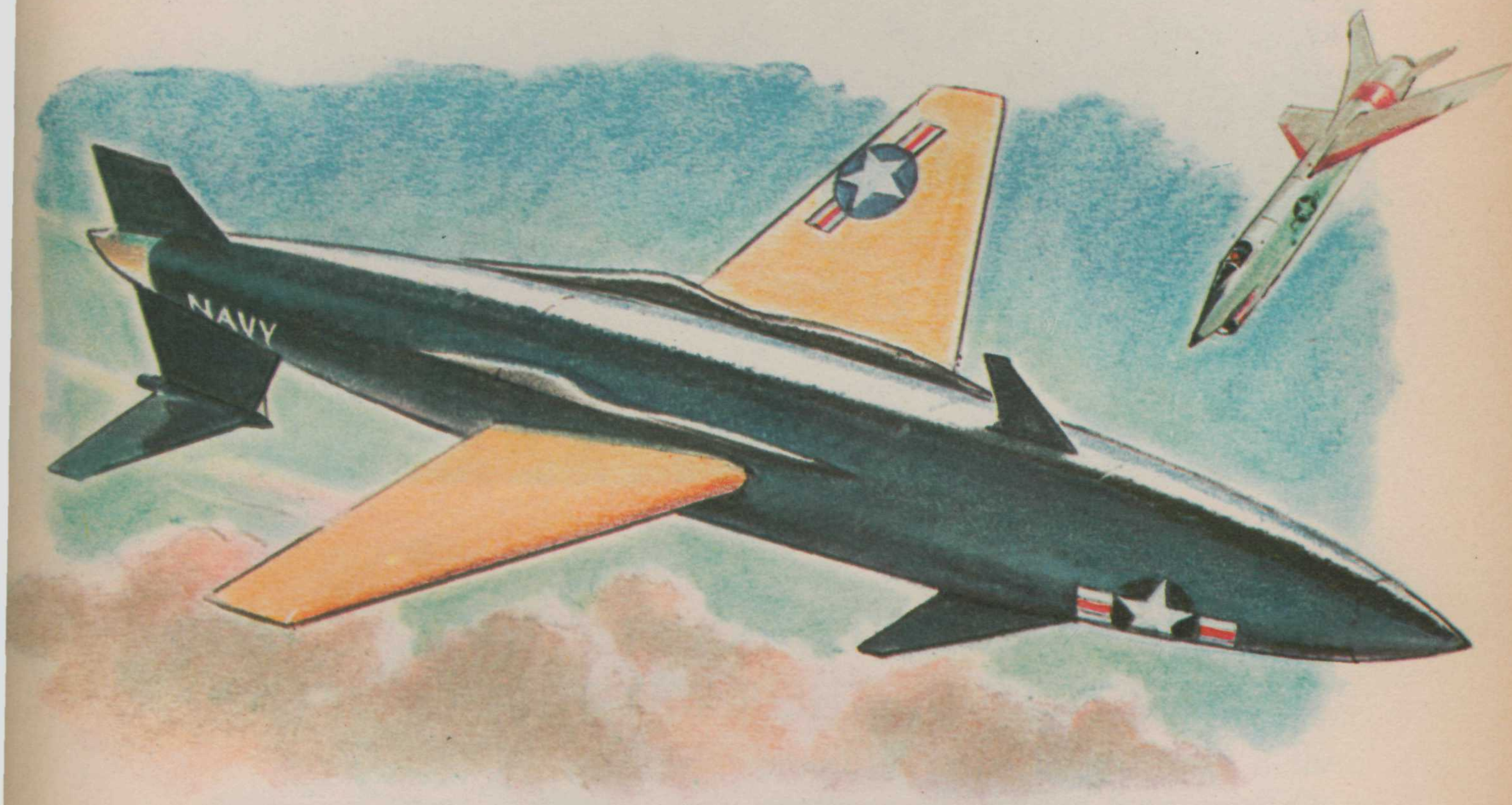


A Nike HERCULES stands ready for firing.

ARE ROCKETS USED TO DRIVE TARGET DRONES?

WITH the speeds of fighter and bomber aircraft increasing every year and the altitude at which they fly increasing, the fighter pilot's need to perfect his air-to-air aim also increases. To fulfill this need, unmanned target drones have been perfected — small replicas of full-scale planes which can reach the same altitudes and speeds. Some are guided and put through their paces by radio-control from a mother plane.

These drones — unless they are hit during practice — are recoverable by parachute. One type — the FIREBEE, is driven by a small jet engine after it has been boosted to top speed by a rocket.



This rocket-powered drone is used for target practice.

THE XKD4R Navy drone is wholly rocket-powered. The body and wings are made of molded plastic, and it can be launched from a fighter aircraft.

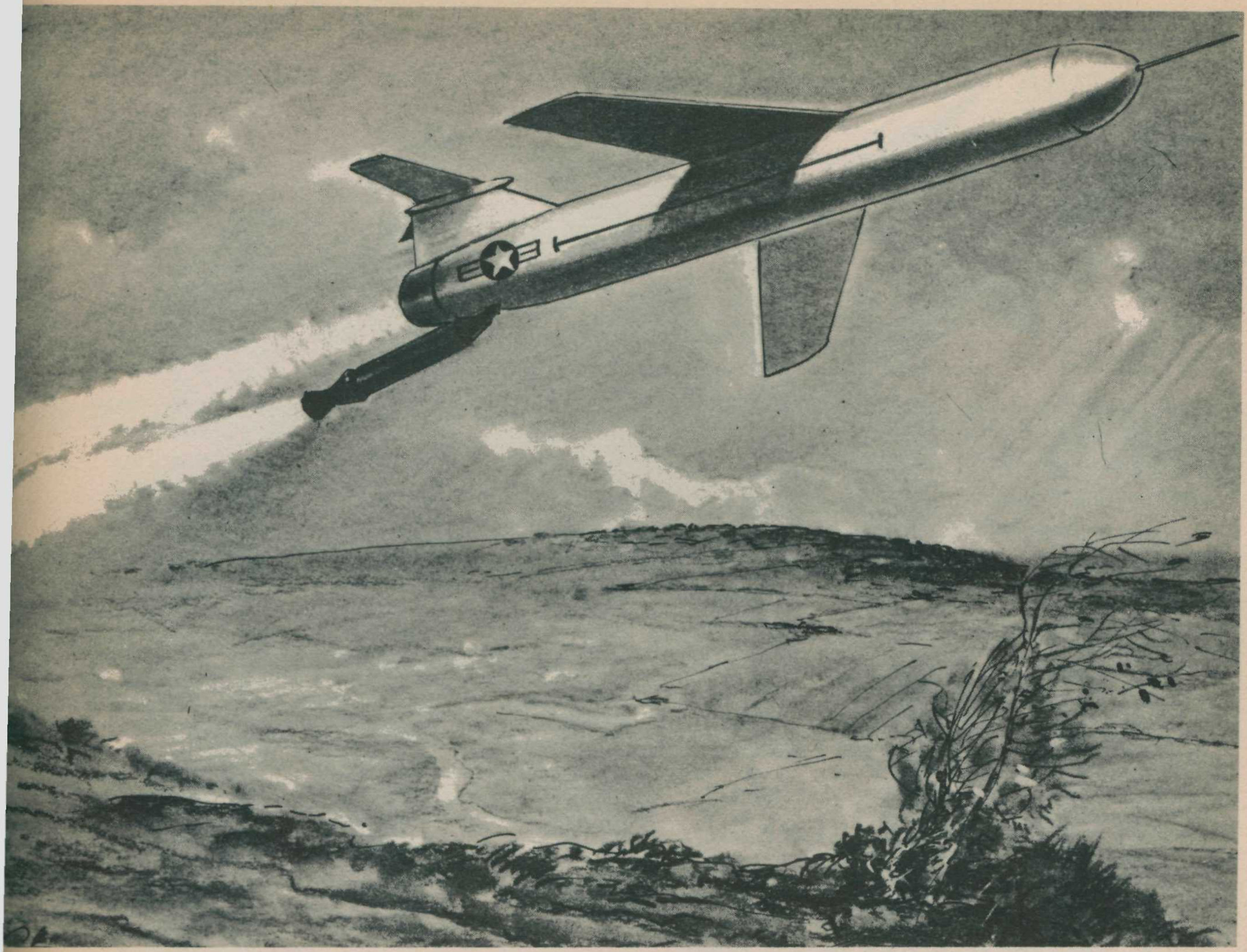
It flies itself, under the mechanical direction of a flight-control package put in place in the fuselage before leaving the ground.

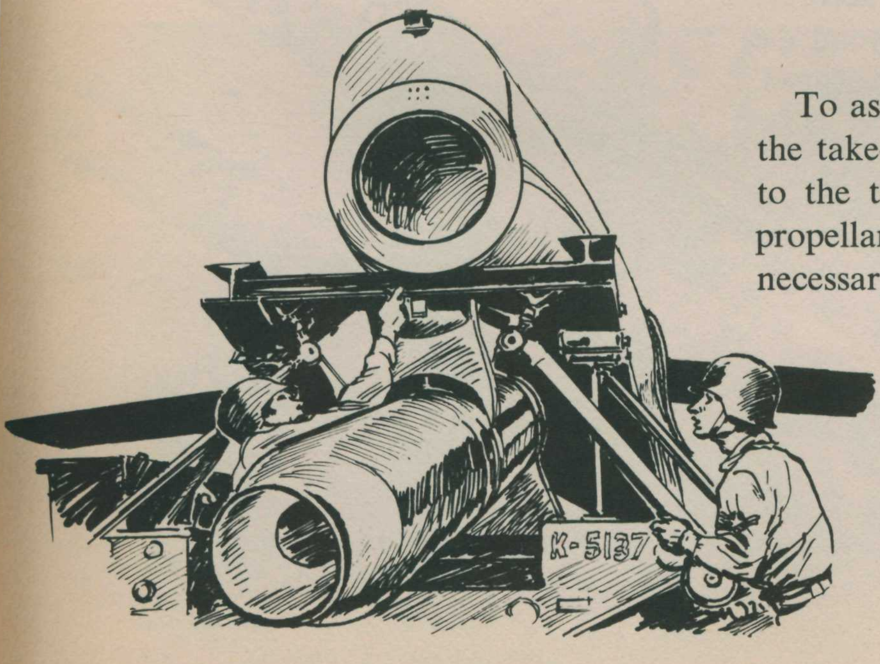
It can duplicate any of the flying characteristics of a full-size plane.

HOW DO ROCKETS "BOOST" JET-PROPELLED MISSILES ON THEIR WAY TO A TARGET?

Air Force combat teams are ready to send the MACE, a pilotless jet-propelled missile with a nuclear warhead, to a target over 600 miles away. These missiles are launched from specially-built powerful vehicles called zero-length-launchers. Near danger points around the world the deadly weapons are hidden along wooded hillsides in Europe, or on tropical coral headlands in the Pacific. Guided after launching, the missile with its fearsome warhead flies to its distant enemy target with unerring accuracy.

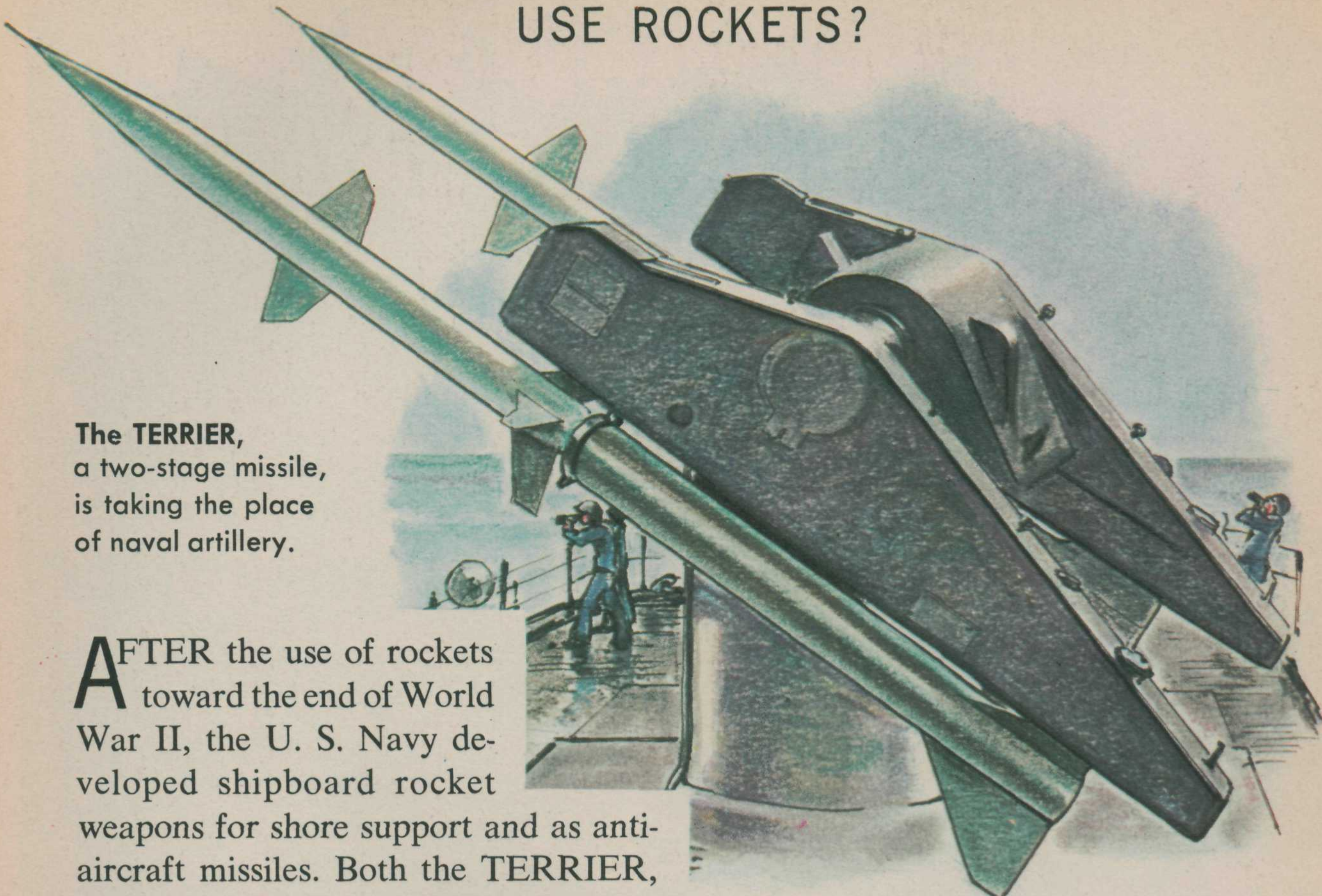
In parts, the MACE and all equipment can be loaded aboard a cargo plane, flown to any part of the world, and be ready for firing within hours.





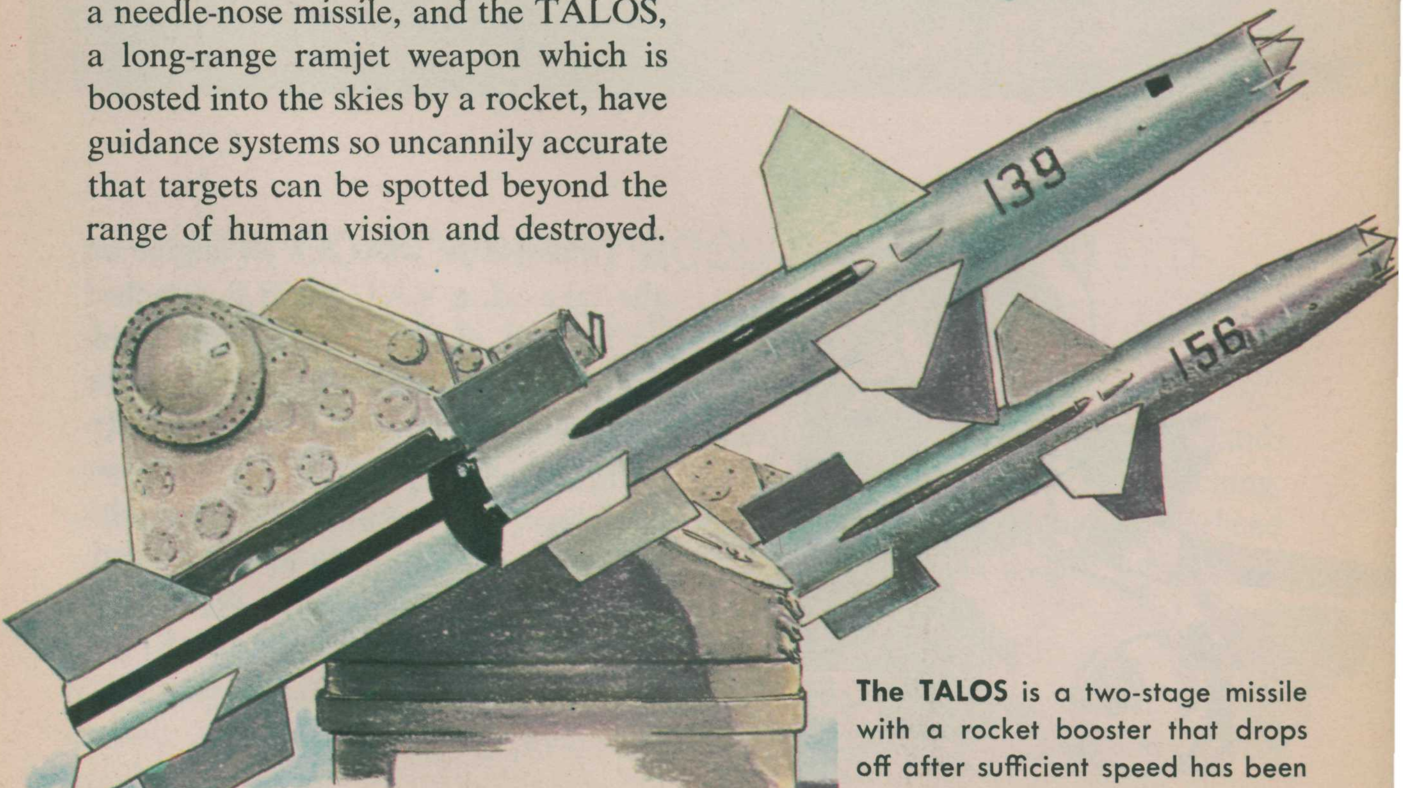
To assist the MACE's jet engine on the take-off, a RATO unit is attached to the tail of the missile. This solid-propellant rocket booster gives it the necessary acceleration toward full flying speed. When this has been achieved and the booster is no longer needed, it falls away, while the MACE goes on alone.

HOW DOES THE UNITED STATES NAVY USE ROCKETS?



The TERRIER, a two-stage missile, is taking the place of naval artillery.

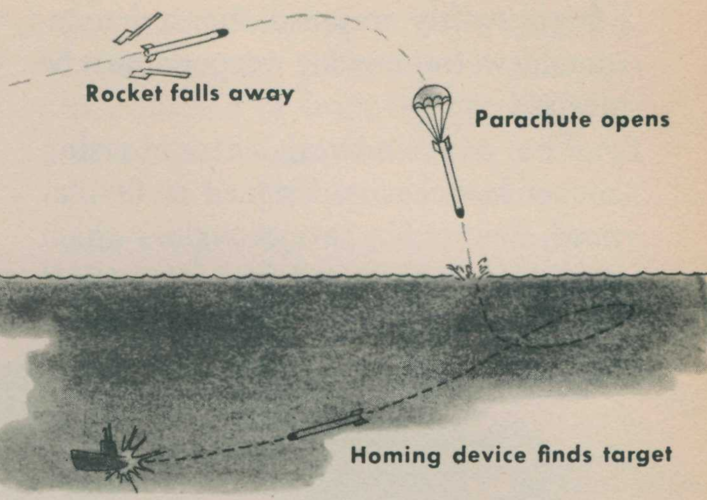
AFTER the use of rockets toward the end of World War II, the U. S. Navy developed shipboard rocket weapons for shore support and as anti-aircraft missiles. Both the TERRIER, a needle-nose missile, and the TALOS, a long-range ramjet weapon which is boosted into the skies by a rocket, have guidance systems so uncannily accurate that targets can be spotted beyond the range of human vision and destroyed.



The TALOS is a two-stage missile with a rocket booster that drops off after sufficient speed has been attained by the missile.

HOW DOES THE UNITED STATES NAVY PLAN TO USE ROCKETS IN UNDERSEA WARFARE?

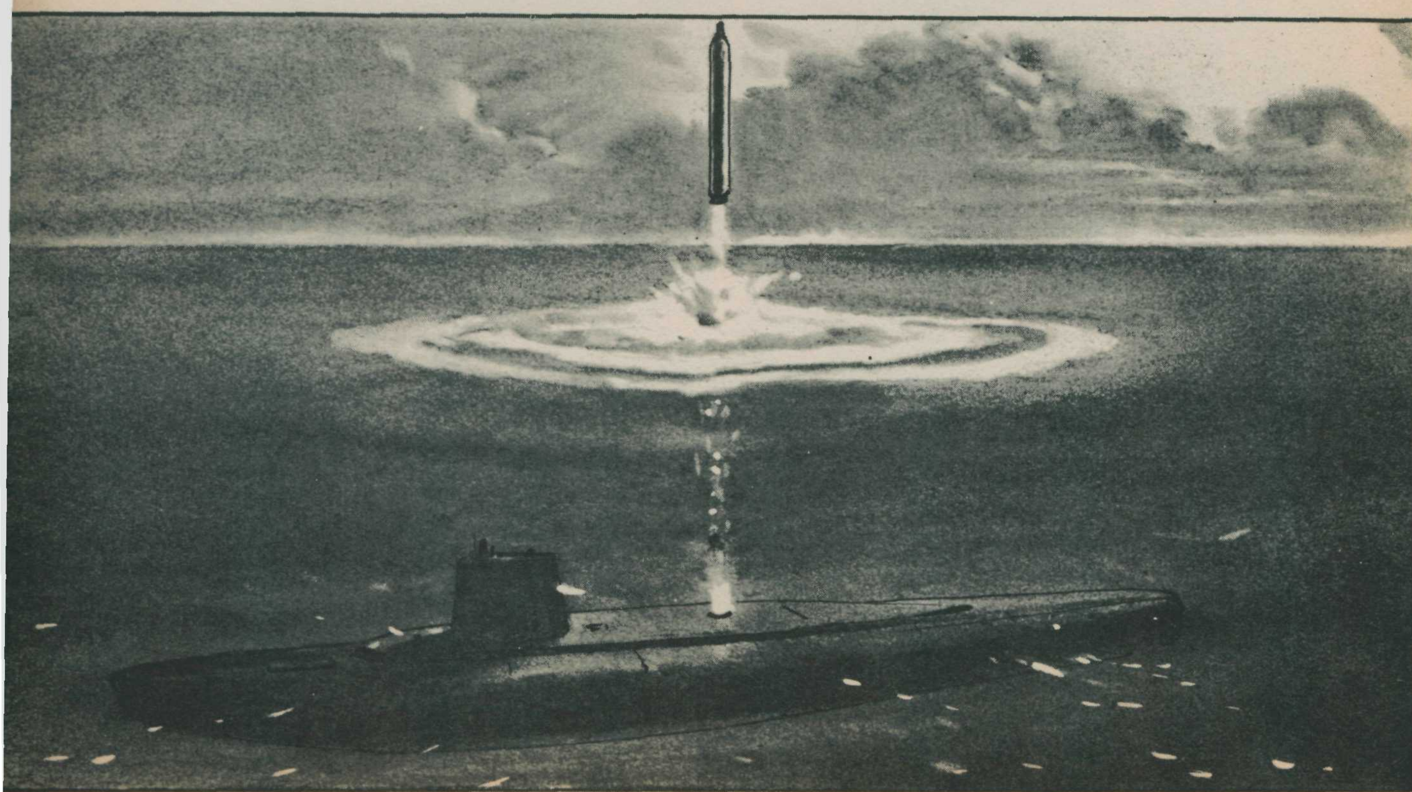
WHEN a lurking enemy submarine is located, surface ships can fire a RAT (rocket-assisted torpedo) toward the suspected area. The rocket hurls the torpedo in the direction of the target, a parachute lowers it into the water close by, and a homing device guides it to the kill.



The U. S. Navy is building a fleet of atomic submarines capable of launching a salvo of POLARIS missiles which can fly supersonically to a target 1,500 miles away.

The submarines can remain submerged far from land for weeks and, when the time comes to strike, can fire their missiles from the depths of the sea or from the surface.

The first successful firing of a ballistic missile from under water took place on July 20, 1960, when a POLARIS missile was fired from the nuclear submarine *George Washington.* At the time of the firing, the *George Washington* was submerged in 50 to 60 feet of water.

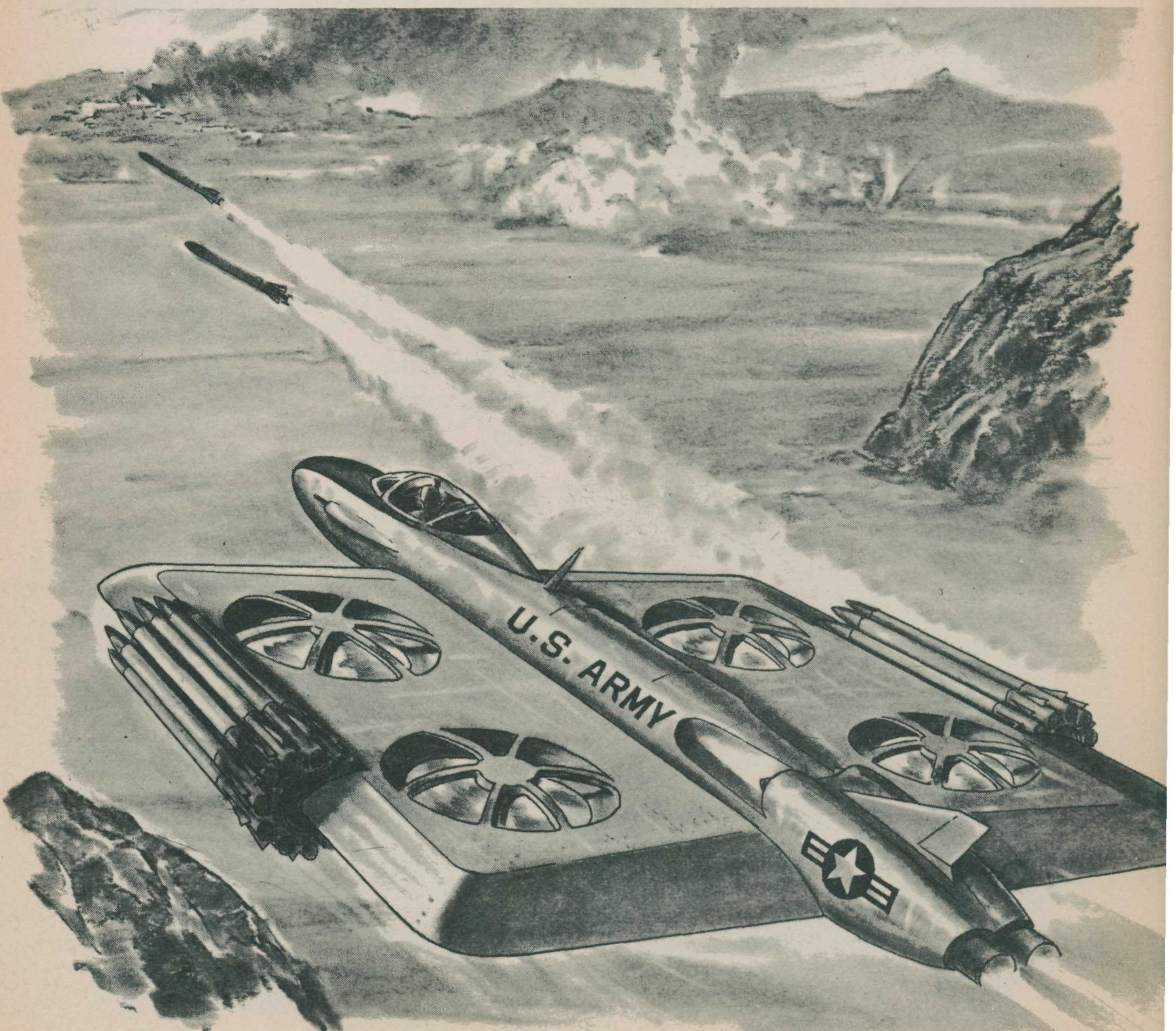


IN WHAT NEW WAYS WILL ROCKETS BE USED?

TO BE sure that atomic battlefields are swiftly occupied after a detonation, new, fast-moving weapons must be devised.

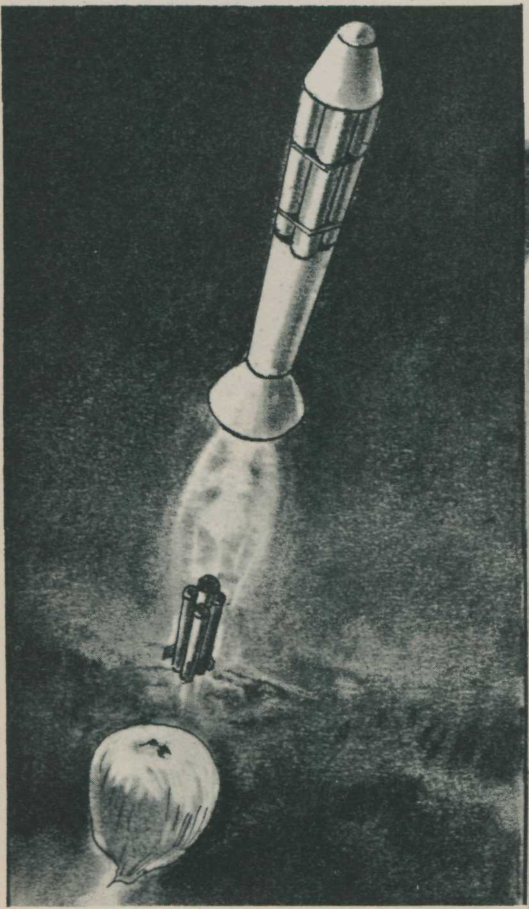
The experimental vertical-rising rocket launcher is designed to fit that need. Powered by two jet engines which also drive four ducted fans for vertical lift, this vehicle is fitted with two revolving banks of rockets that can be fired singly or in salvos to give support to advancing battle groups.

Kept in hiding behind a rampart of mountains, the rocket launchers can proceed to the atomic blast site as soon as radiation lifts, in order to cover the occupation of the battlefield by ground forces without delay.

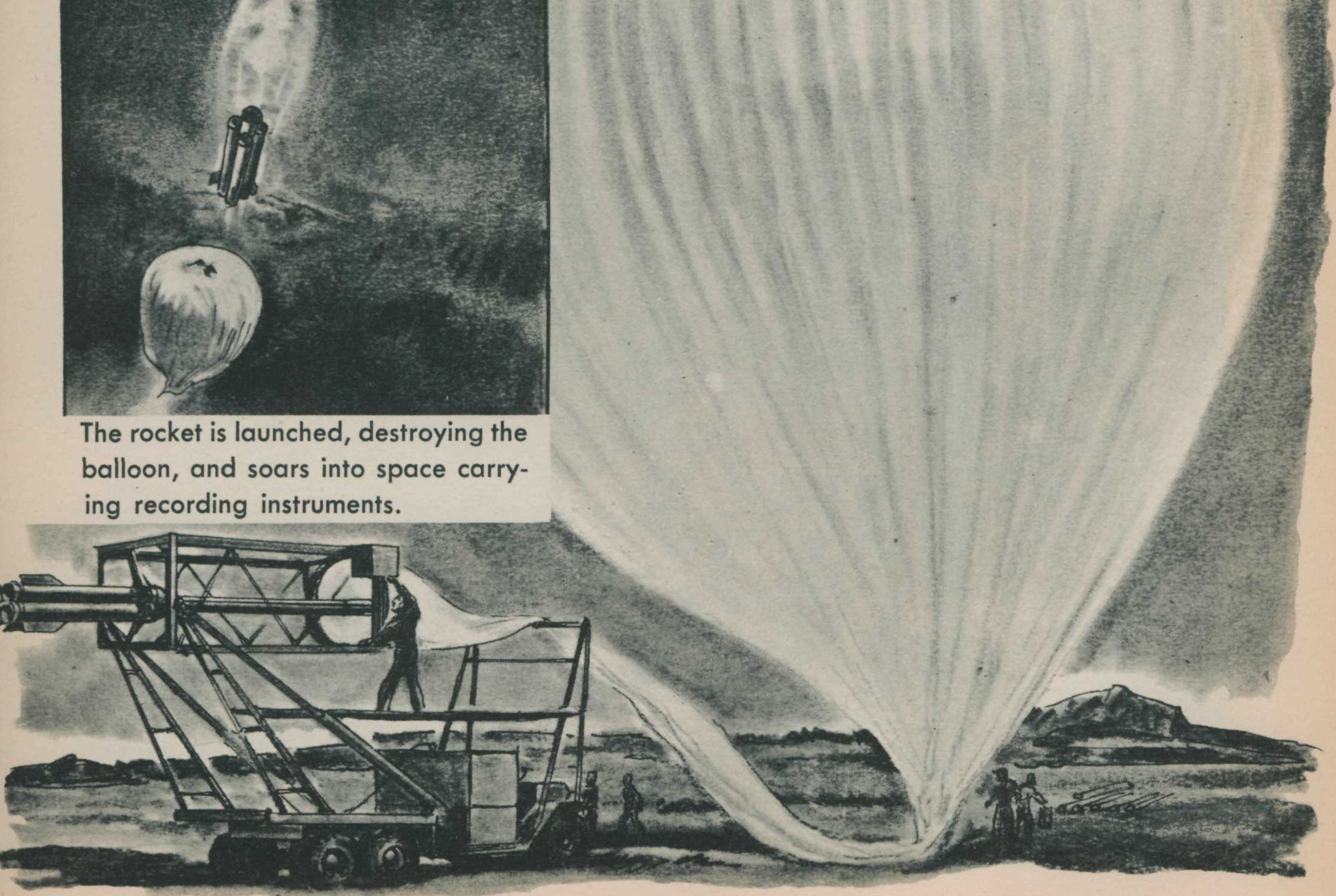


HOW IS FUEL CONSERVED IN LAUNCHING PROBE ROCKETS?

INSTEAD of firing rockets from pads at ground level, the U. S. Air Force, in "Project Farside," sent a multi-stage missile to 100,000 feet altitude, suspended by a polyethylene balloon. At that point the rockets were triggered. Launching the rockets from this altitude instead of from the ground, conserved fuel. Some of them have soared 4,000 miles into space, sending back data on micro-meteorites, temperature and radiation.

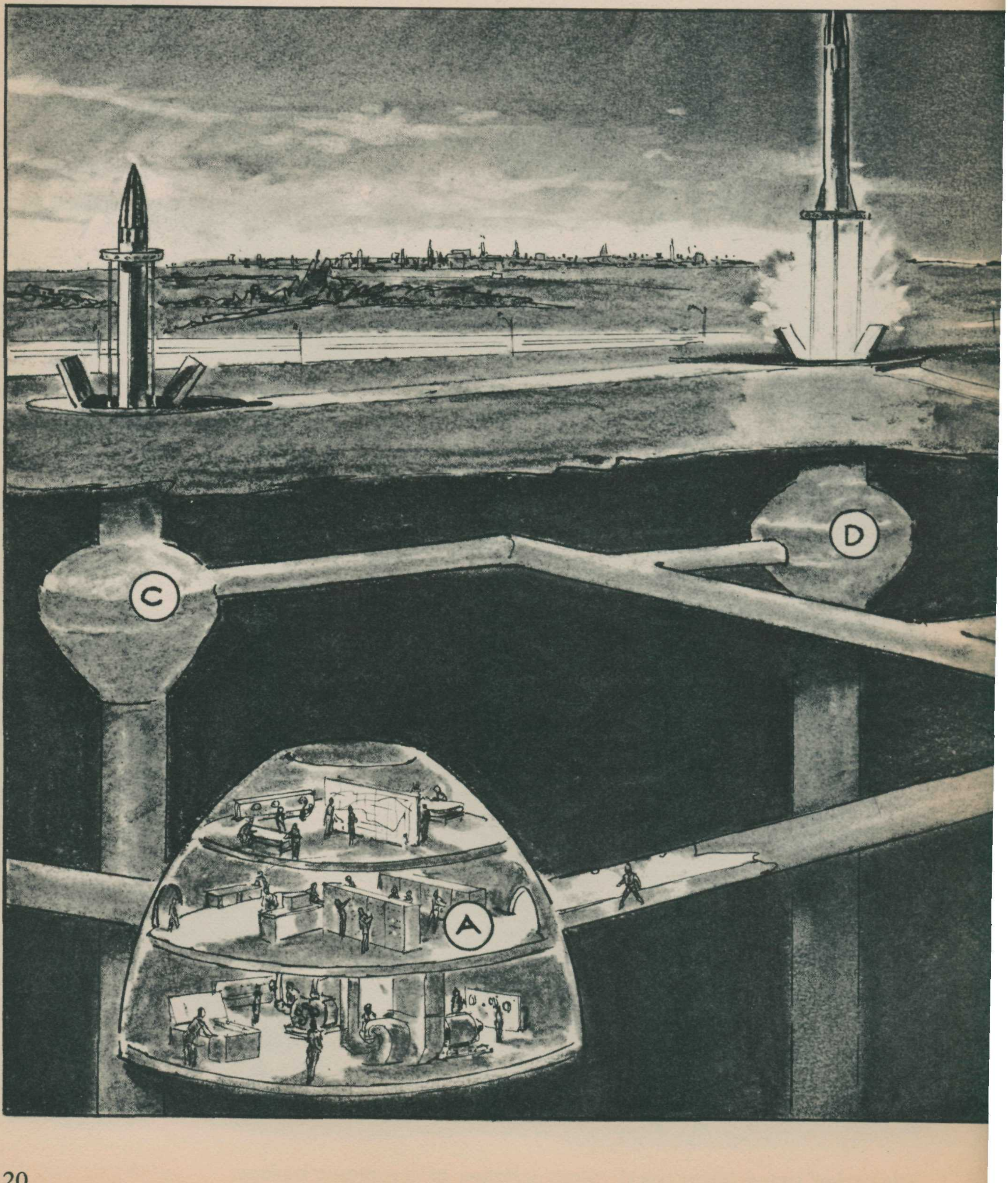


The rocket is launched, destroying the balloon, and soars into space carrying recording instruments.

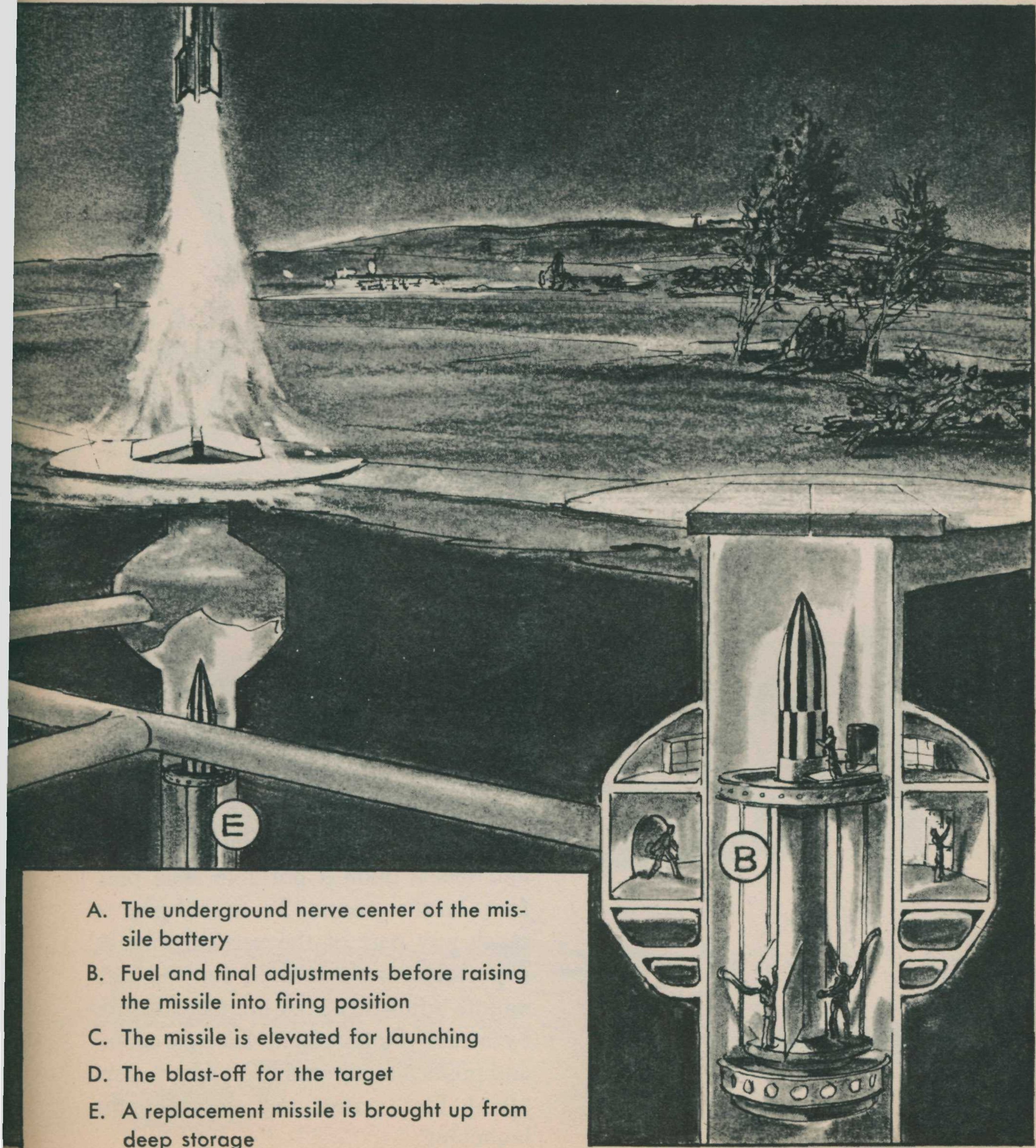


The rocket frame (on a truck) awaits inflation of the plastic balloon.

HOW WILL PERMANENT MISSILE BASES BE CONSTRUCTED FOR INSTANT USE AGAINST ENEMY ATTACK?



HIDDEN deep below the ground in concrete silos, intercontinental missiles stand ready for quick firing in the case of attack. Within an underground labyrinth, the missile battery control center has computers, fueling facilities, and supply and living quarters. When the alarm is sounded, concrete trap doors open and the missiles are brought above ground, their aim and range data already set. The Launch Officer can fire them singly or in salvos.

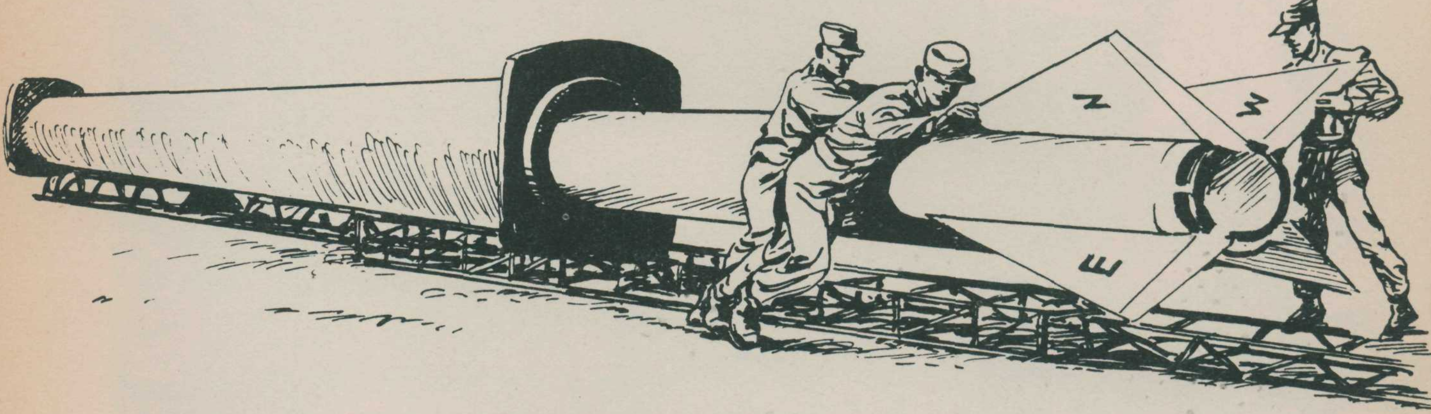


A. The underground nerve center of the missile battery
B. Fuel and final adjustments before raising the missile into firing position
C. The missile is elevated for launching
D. The blast-off for the target
E. A replacement missile is brought up from deep storage

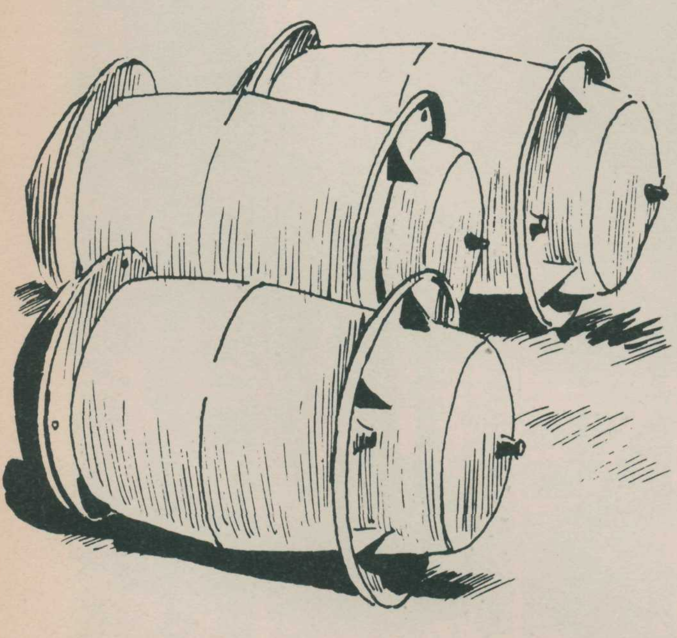
HOW ARE MISSILES LAUNCHED WHERE THERE ARE NO PERMANENT BASES?

THE UNITED STATES ARMY'S CORPORAL missile is delivered to the men in the field encased in a pressurized cylinder 50 feet long, to guard its delicate instrumentation from damage. After it is removed from this protective tube, the nose cone and tail fins are secured in place and a giant transporter vehicle takes the missile to the fueling station where chemicals are pumped into it from steel fuel tanks.

Without the launching facilities to be found at a permanent missile base, all sorts of strange vehicles are needed.

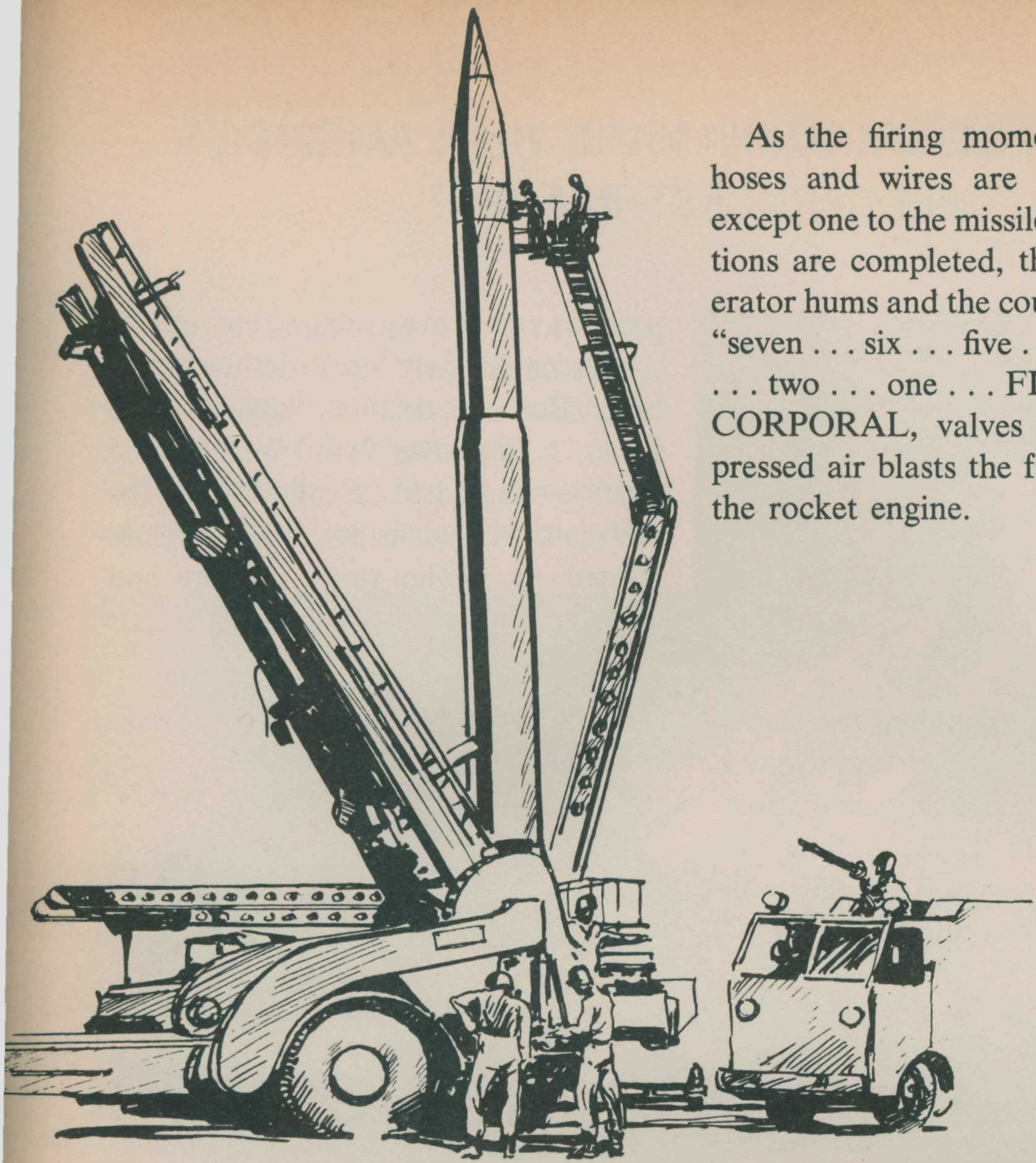


Missile being removed from shipping case



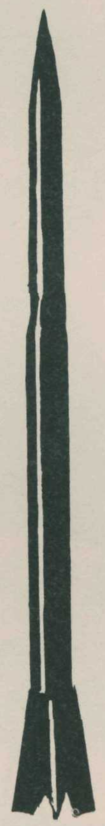
These tanks contain aniline, a fuel used in the launching of missiles.

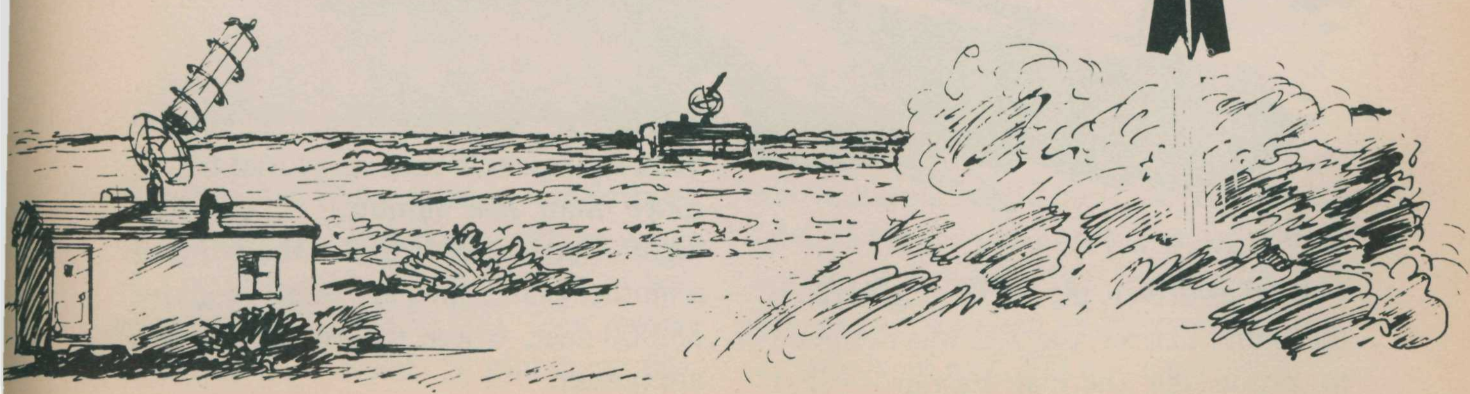
Vans which house radar tracking instruments and electronic computers must be placed in position. The transporter slowly points the missile upward and sets it upon a portable steel platform on the ground. To enable men to reach any part of the vertical missile, a portable crane is used for the last-minute adjustments. A fire truck stands by in case of an accident. Electric cables and hoses may be seen everywhere, supplying fuel, power and data for the launching.



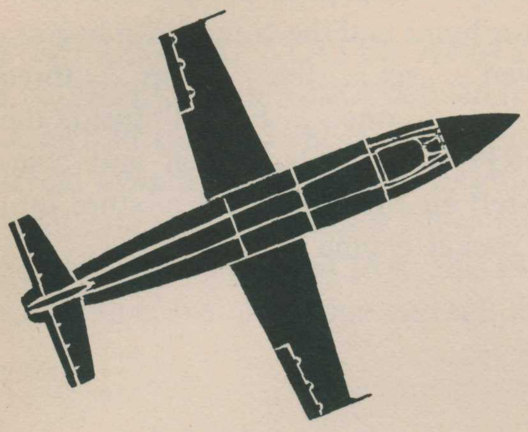
As the firing moment approaches, hoses and wires are reeled in — all except one to the missile. Final preparations are completed, the portable generator hums and the countdown begins: "seven . . . six . . . five . . . four . . . three . . . two . . . one . . . FIRE!" Inside the CORPORAL, valves open and compressed air blasts the fuel mixture into the rocket engine.

A roar is heard, dust scatters in an explosive cloud around the base of the missile and — ever so slowly at first — the CORPORAL begins its fire-trailing ascent into the sky. Two miles up, it tilts and screams off toward a target 60 to 70 miles away.

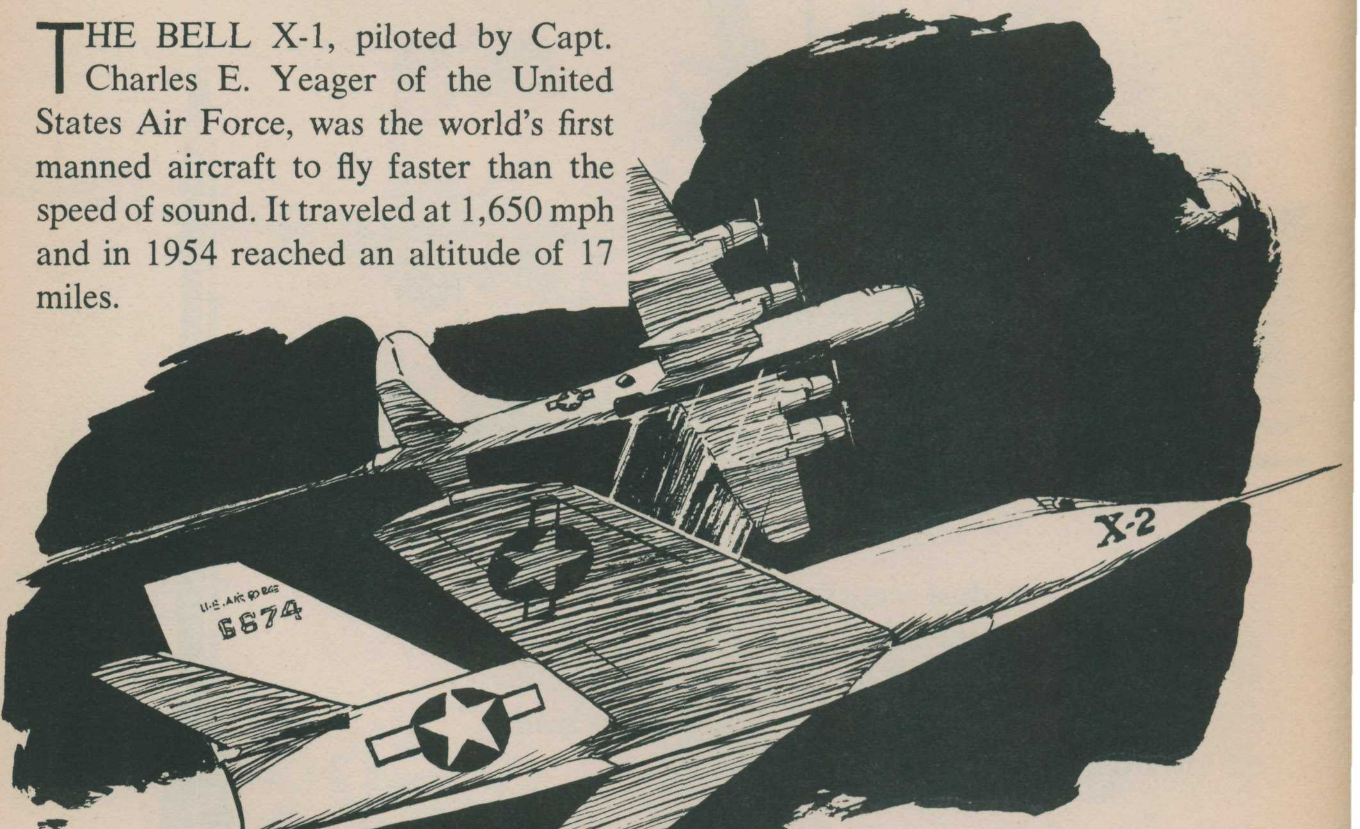




WHAT RECORDS WERE MADE WITH AMERICA'S FIRST ROCKET PLANES?



THE BELL X-1, piloted by Capt. Charles E. Yeager of the United States Air Force, was the world's first manned aircraft to fly faster than the speed of sound. It traveled at 1,650 mph and in 1954 reached an altitude of 17 miles.



Rocket-driven planes having broken the sound barrier, the X-2 was designed to probe the thermal barrier — that point at which it was feared the terrific speeds might melt the structure of the craft. Built of titanium (lighter than steel), it flew over 2,100 mph and in 1956 it climbed to 25 miles above the surface of the earth. Its rocket engines burned an alcohol-water mixture and used liquid oxygen as an oxidizer.

The "X" series of rocket planes are built for research and carry fuel for no more than five minutes of powered flight. Carried aloft under the wing of a mother plane, they are released above 35,000 feet, where the rocket engines are ignited.

WHAT DOES THE X-15 ACCOMPLISH?

THE X-15, an experimental rocket plane, was developed for manned rocket research at the very edge of space, above 99.99 per cent of the earth's atmosphere. The X-15 carries out its research above the desert near Edwards Air Force Base in California.

The X-15 is carried beneath the wing of a B-52 bomber to an altitude of between 40,000 to 50,000 feet, from where it is released. It plummets for 1,500 feet, and then its 600,000-horsepower engine ignites and burns for 90 seconds. The rocket plane flashes upward toward cislunar space. After the rocket has burned out, the X-15 still continues upward for thousands of feet and then arches downward, reentering the thicker atmosphere. It glides back to earth and, using skis instead of wheels, lands on the desert.

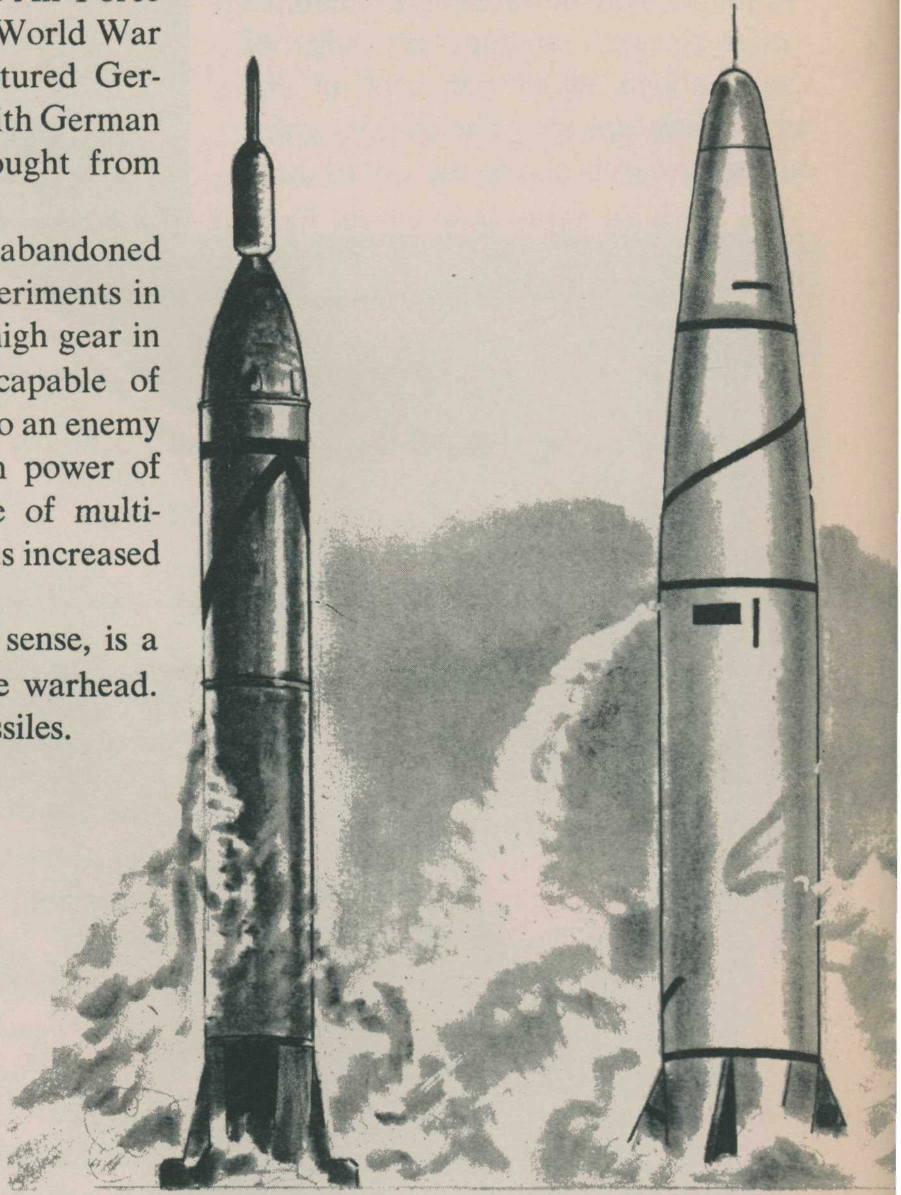
The X-15 has soared to 67 miles above the earth and has reached speeds of 4,534 miles per hour, nine times the speed of sound. The newest X-15 planes are designed to fly even higher, at speeds up to 5,300 miles per hour.

WHICH ARE THE UNITED STATES LONG-RANGE MISSILES?

MISSILE experiments in the United States Army, Navy and Air Force began soon after the end of World War II, when a quantity of captured German V-2 missiles, together with German rocket specialists, were brought from Europe.

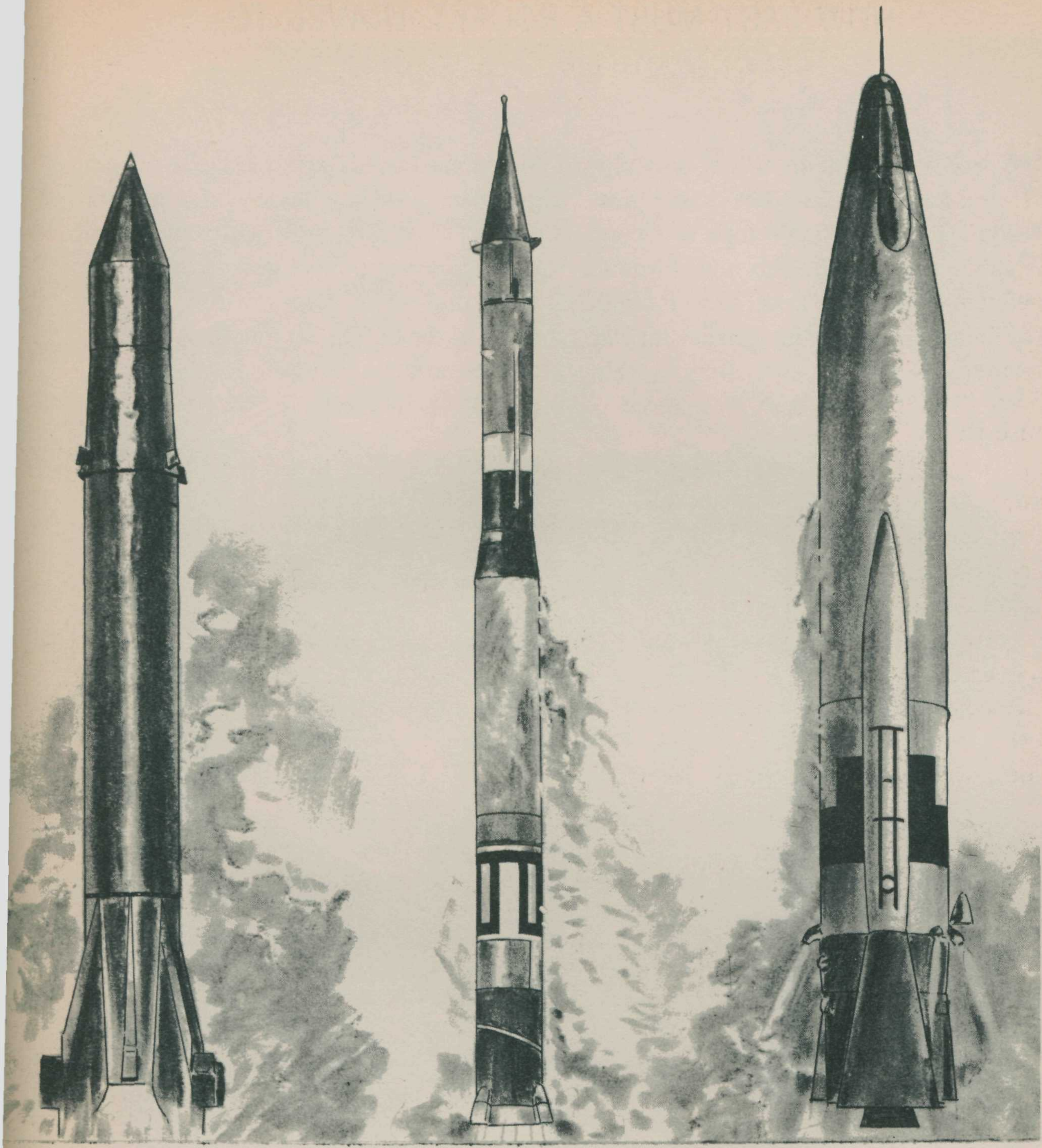
Rocket building, almost abandoned since Robert Goddard's experiments in the early 1900's, went into high gear in order to perfect missiles capable of carrying a nuclear warhead to an enemy target. With the increase in power of rocket engines and the use of multi-stage missiles, their range was increased to over 5,000 miles.

A missile, in the military sense, is a rocket carrying an explosive warhead. Thus, not all rockets are missiles.



Larger and more powerful than any missile booster is the *Saturn 5* rocket. It is 278 feet tall and weighs 3,000 tons. Its five 1,500,000-pound-thrust engines give it a total thrust of 7,500,000 pounds, making it the world's most powerful rocket. The first launching of a *Saturn 5* took place November 9, 1967. A little more than a year later, a *Saturn 5* boosted the *Apollo 8* spacecraft on man's first journey to the moon.

	JUPITER	THOR
Service Branch	U.S. Army	U.S. Air Force
Height (feet)	58	62
Weight (pounds)	105,000	110,000
Range (miles)	1,50Q	1,500
Contractor	Chrysler	Douglas



REDSTONE	VANGUARD	ATLAS
U.S. Army	U.S. Navy	U.S. Air Force
69	72	75
?	22,000	243,000
200+	300 Mi. Alt.	9,000
Chrysler	Martin	Convair

HOW FAST MUST A ROCKET TRAVEL TO ESCAPE EARTH'S GRAVITATIONAL PULL?

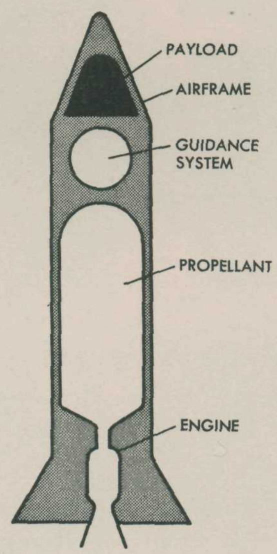
TO GO to the moon — our only natural satellite—a rocket missile must attain a speed of 25,000 mph to escape from the earth's pull. This must be done with multi-stage rockets, each individual stage sending the missile farther into space and at increasing speed. When the last stage is fired, the missile must be traveling at seven miles per second. At this point it will continue to coast, without power, and scientists believe that as it comes within 30,000 miles of the moon, the missile will begin to orbit around that body.

This is the track of a missile, launched to circle the moon. Although the moon has a low gravitational pull, the missile will circle closer and closer and eventually fall to the moon's surface.

HOW DOES A ROCKET WORK?

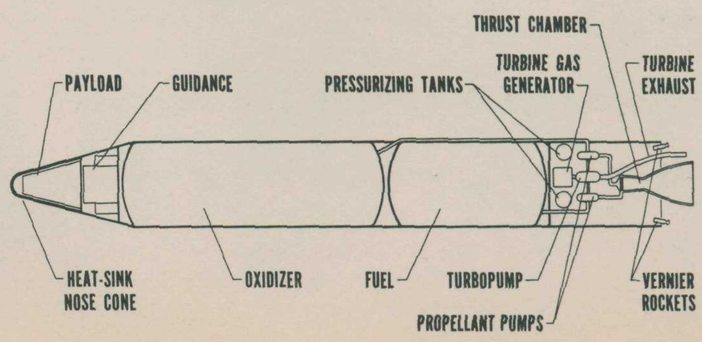
THE MIGHTY *Saturn 5* and the Fourth of July skyrocket have much in common. They both work on the same principle, relying for success on a law of motion discovered by Sir Isaac Newton, a brilliant mathematician and scientist. It states that *for every action, there is an equal and opposite reaction*. In other words, whenever a force exerts a push or a pull on an object in one direction (an action), the object itself exerts an equal push or pull in the opposite direction (a reaction). If you fire a gun, it moves backward — it recoils, or "kicks" — against your shoulder with a force equal to that of the bullet moving forward out of the gun barrel. The bullet moving forward is an action, and the gun moving backward is a reaction. As another example of Newton's reaction principle, if you jump forward off a scooter, the scooter itself moves backward. Your forward jump is the action; the scooter's move backward is the reaction. When burning gas rushes out of the rear of a rocket, it is an action whose reaction is the forward motion of the rocket. Tons of burning gas rush out of the rear of *Saturn 5* every second and give the rocket its 7½-million-pound thrust.

The burning gas is produced by ignited rocket fuel. There are two main types of rocket fuel: solid and liquid. Some solid fuels are black gunpowder, smokeless powder, and a chemical that is principally rubber. Among the liquid



Components (and their distribution) in a typical rocket.

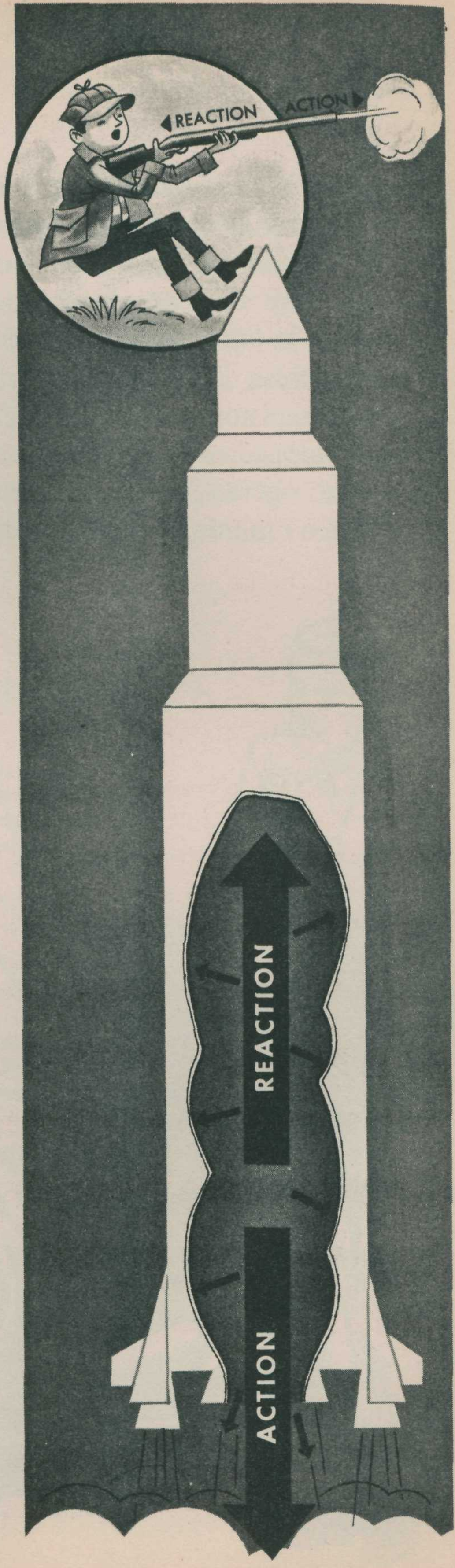
fuels in use are hydrogen peroxide (the same liquid that is a household antiseptic, only much more concentrated and purer), alcohol, gasoline, hydrogen, fluorine, and liquid oxygen. Rocket fuels are better termed rocket propellants.



CHEMICAL ROCKET
LIQUID PROPELLANT

A solid propellant is easiest to use. The solid-propellant rocket engine need consist only of a place to burn the propellant (a combustion chamber), an exhaust nozzle at the rocket's rear, and a device to ignite the propellant. Liquid propellants are much more complicated to use than solid ones. The liquid-propellant rocket engine consists of at least two storage tanks, and pumps force the propellant through pipes to the combustion chamber. A power system for the pumps and many kinds of controls are also necessary parts of the liquid-propellant rocket. To compensate for a more complicated combustion system, though, a liquid-propellant rocket has certain advantages: it can be made more powerful than a solid propellant engine; the thrust of the engine can be varied (a solid-propellant engine's thrust cannot); some liquid propellant engines can be stopped and restarted while the rocket is in flight, whereas solid propellants can only be stopped and not restarted; and finally, liquid propellants cost less than solid propellants.

A large modern rocket with hundreds of thousands of parts and requiring dozens of men to launch it is not very much like a Fourth of July skyrocket . . . yet there is no difference in the principle that moves either the huge rocket or the small one. It is Newton's fundamental reaction law that drives all rockets on their flights.



For every action, there is an equal and opposite reaction.

WHY MUST ROCKETS BE USED FOR TRAVEL IN OUTER SPACE?

WHEN man flies through the ionosphere — extending from 50 to 500 miles above the earth — and continues into the exosphere, he will be arriving in outer space where no atmosphere exists. Long before this point is reached, piston and jet engines would have stopped running because, to continue to operate, they must draw in air (oxygen) to mix with the fuel they use.

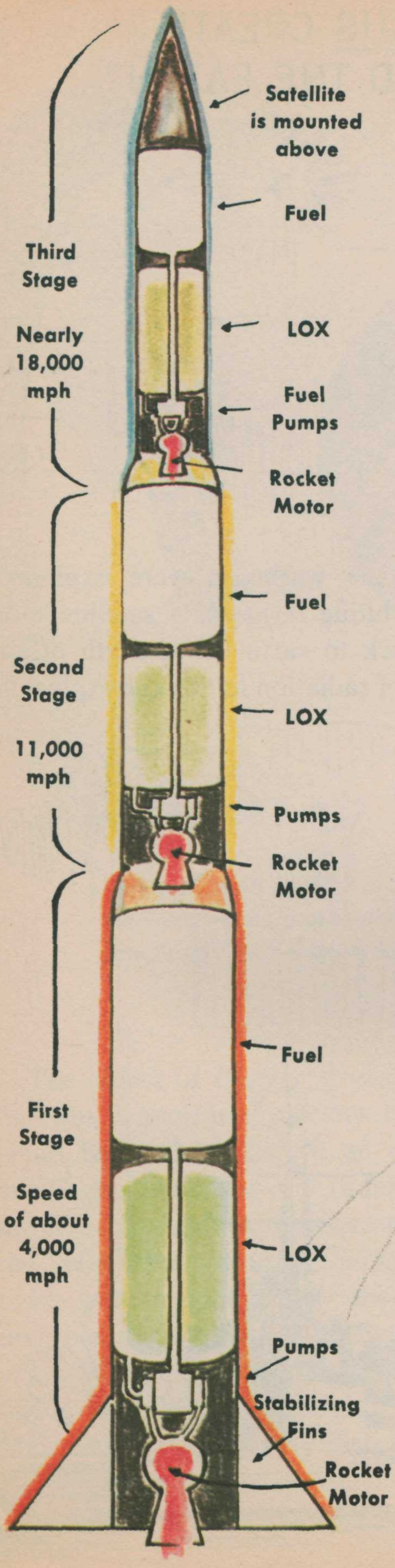
It was the American rocket scientist, Robbert Goddard who first proved, both mathematically and by actual test, that a rocket will work in a vacuum. Its fuel, when mixed with liquid oxygen (often called LOX) in the firing chamber, will explode and burn, creating *thrust*. Therefore, the rocket engine is unlike any other in that it carries its own "air" with it.

Another of its advantages for manned space travel is that its speed of acceleration can be so controlled by the flow of fuel, that the initial "blast-off" from the ground can be kept at speeds man can stand.

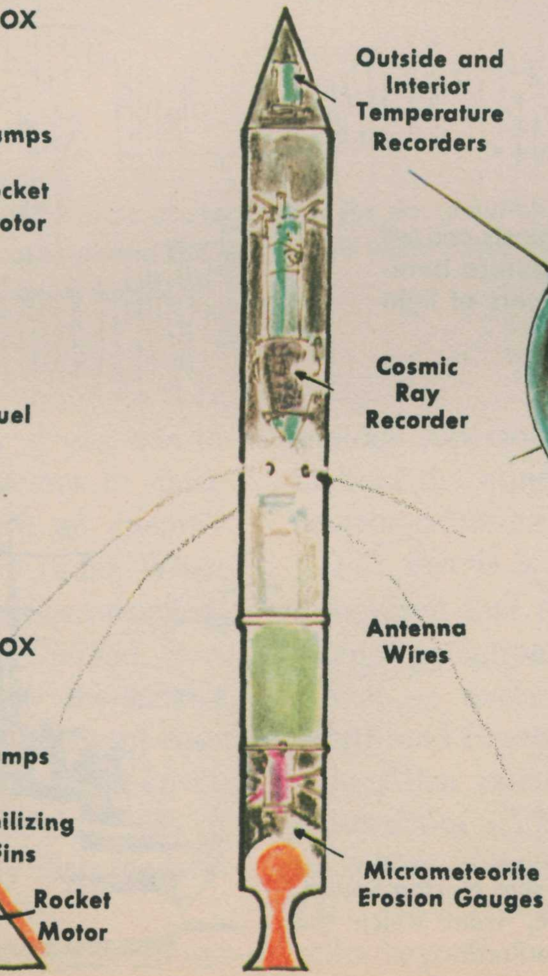
This four-barreled rocket engine, weighing only 210 pounds, produced 6,000 pounds of *thrust*. It pushed the X-1 through the sonic barrier to a height of 90,000 feet.

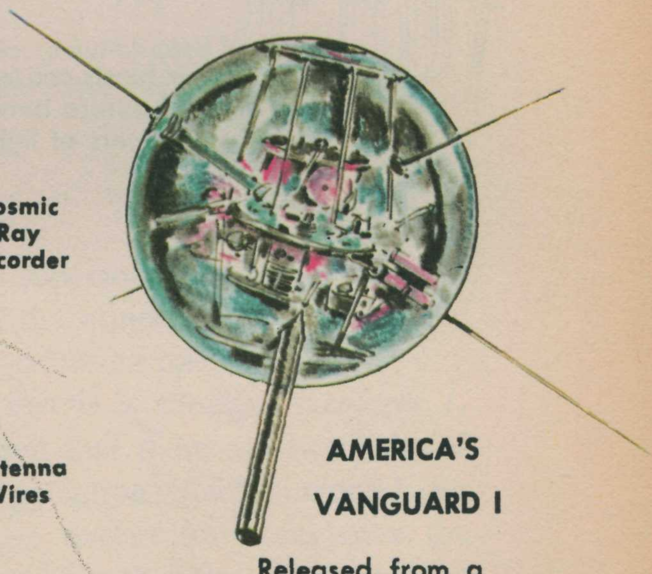
HOW IS A MULTI-STAGE MISSILE CONSTRUCTED?

IT WAS America's own Dr. Goddard who first discovered that by mounting one rocket atop another — automatically firing the next stage above when the first had burned out — speeds and distances could be achieved that were impossible with a single-stage rocket. In some instances, the instrument-carrying satellite has its own rocket engine which goes into orbit, too.



EXPLORER I SATELLITE

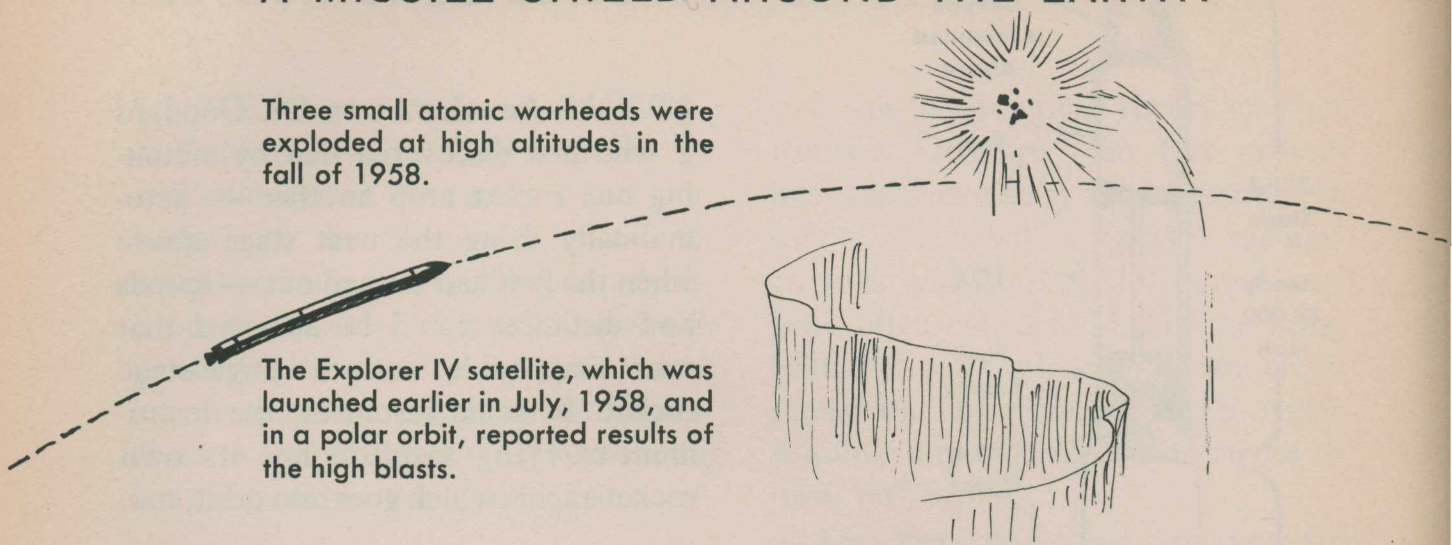




AMERICA'S VANGUARD I

Released from a protective nose cone, this instrumented satellite goes into orbit.

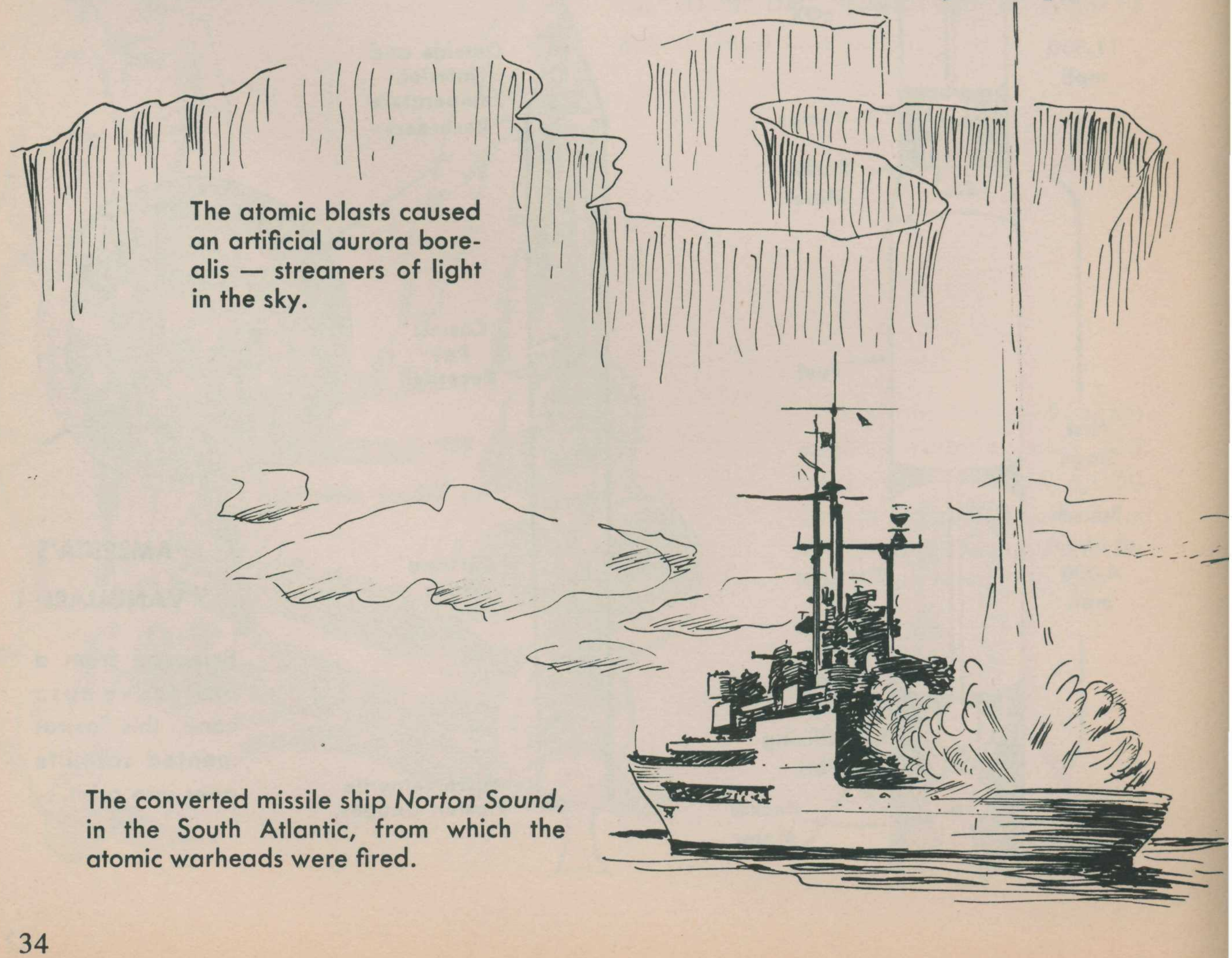
HOW DID PROJECT ARGUS CREATE A MISSILE SHIELD AROUND THE EARTH?



Three small atomic warheads were exploded at high altitudes in the fall of 1958.

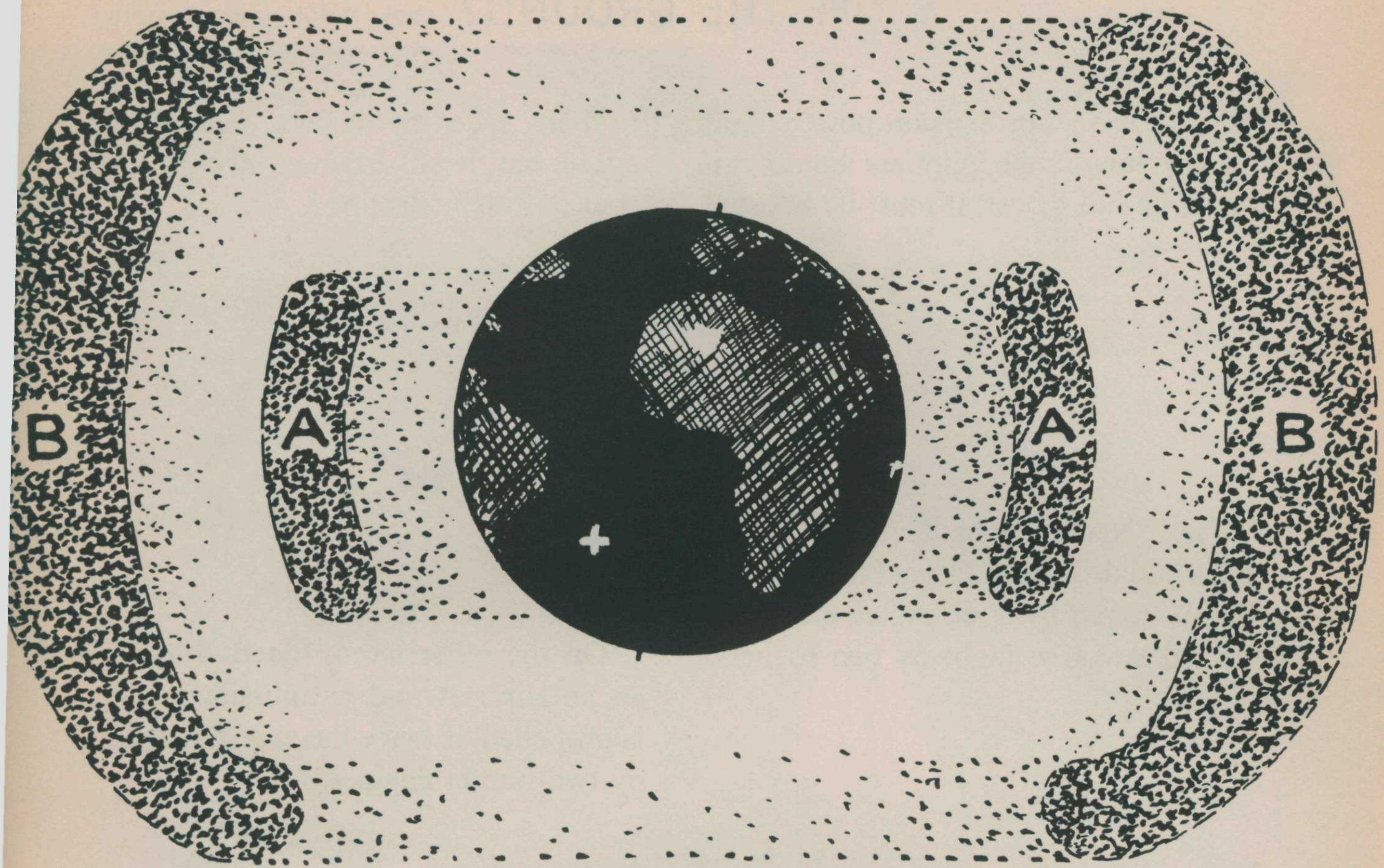
The Explorer IV satellite, which was launched earlier in July, 1958, and in a polar orbit, reported results of the high blasts.

IN the autumn of 1958, three rockets with nuclear warheads were secretly fired above the South Atlantic Ocean to an altitude of three hundred miles, where the warheads were exploded. The orbiting *Explorer 4* satellite radioed back to earth the strength of the cloud of radiation left by the explosion.



The atomic blasts caused an artificial aurora borealis — streamers of light in the sky.

The converted missile ship *Norton Sound*, in the South Atlantic, from which the atomic warheads were fired.



Areas marked A and B are cross sections of the doughnut-shaped Van Allen radiation belts that surround the earth. The white cross marks the site of the Project Argus experiment.

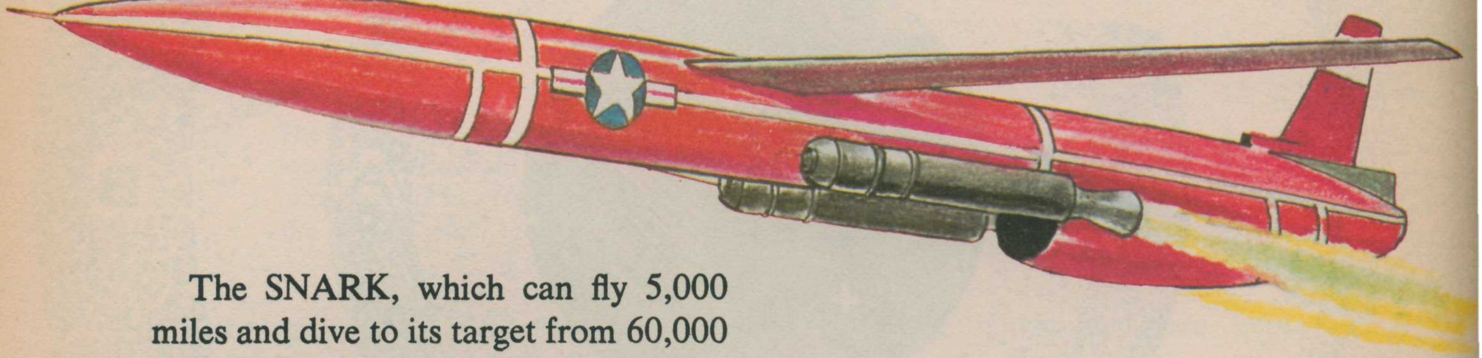
The object of *Project Argus* was to find out if nuclear explosions in space could be used to disrupt an enemy's missile-guiding radar and radio. When the 300-mile-high explosions occurred, the released negatively charged electrons were caught up by the earth's invisible magnetic field and swept eastward. Within an hour, they had enveloped our planet with a thin veil of radiation that effectively disrupted radio and radar transmissions.

Many scientists believe that a way to explode supersonic missiles harmlessly high in the atmosphere is to explode neutron-releasing nuclear bombs.

The first U.S. satellite, *Explorer 1*, discovered that there are two belts of intense radiation which surround our planet — except for areas over the North and South Poles. These are the Van Allen radiation belts. One (A) exists about 3,500 miles beyond our atmosphere. Another belt of radiation (B) exists between 8,000 and 12,000 miles beyond our atmosphere.

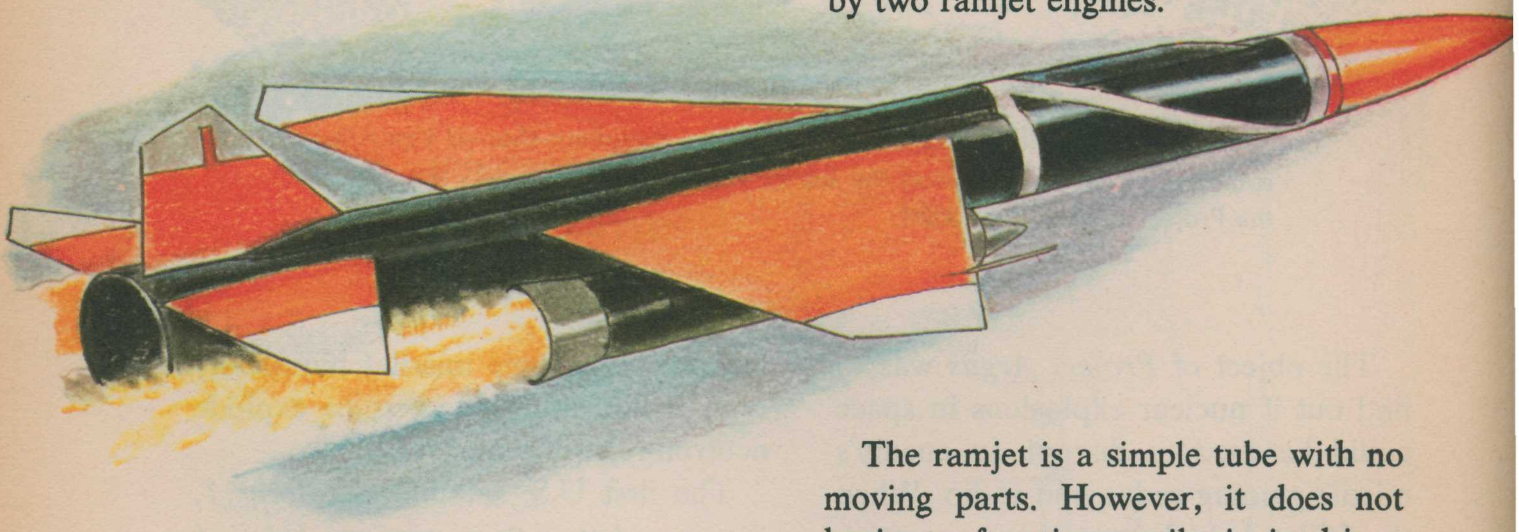
MUST PILOTLESS MISSILES BE ASSISTED OFF THE GROUND?

Until the jet-propulsion power plant of any long-range pilotless bomb can reach its full thrust, it must be boosted to flying speed by rockets. When flying speed has been attained, the booster rockets can be dropped.

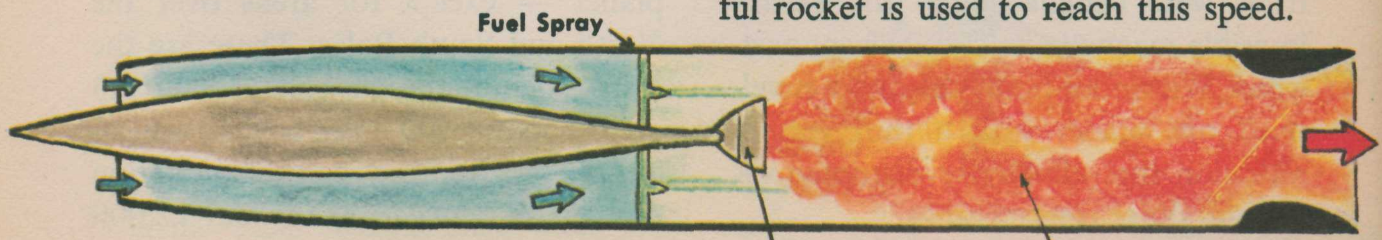


The SNARK, which can fly 5,000 miles and dive to its target from 60,000 feet, is driven by a jet engine after it is hurtled into free flight by two rockets.

On the other hand, the BOMARC, an antiaircraft and antimissile missile, is propelled at twice the speed of sound by two ramjet engines.



The ramjet is a simple tube with no moving parts. However, it does not begin to function until air is driven through it at very high speed. A powerful rocket is used to reach this speed.



The tall structure at the left, used to fuel and service each separate stage of the missile, is rolled back before the firing takes place.

WHAT WAS THE FIRST UNITED STATES SATELLITE PUT INTO ORBIT AROUND THE EARTH?

ON January 31, 1958, a Jupiter-C missile was launched from Cape Canaveral, Florida. An Army Redstone — the first stage — sent it 60 miles up. At 212 miles the ground controller tipped the vehicle to a course parallel with the earth.

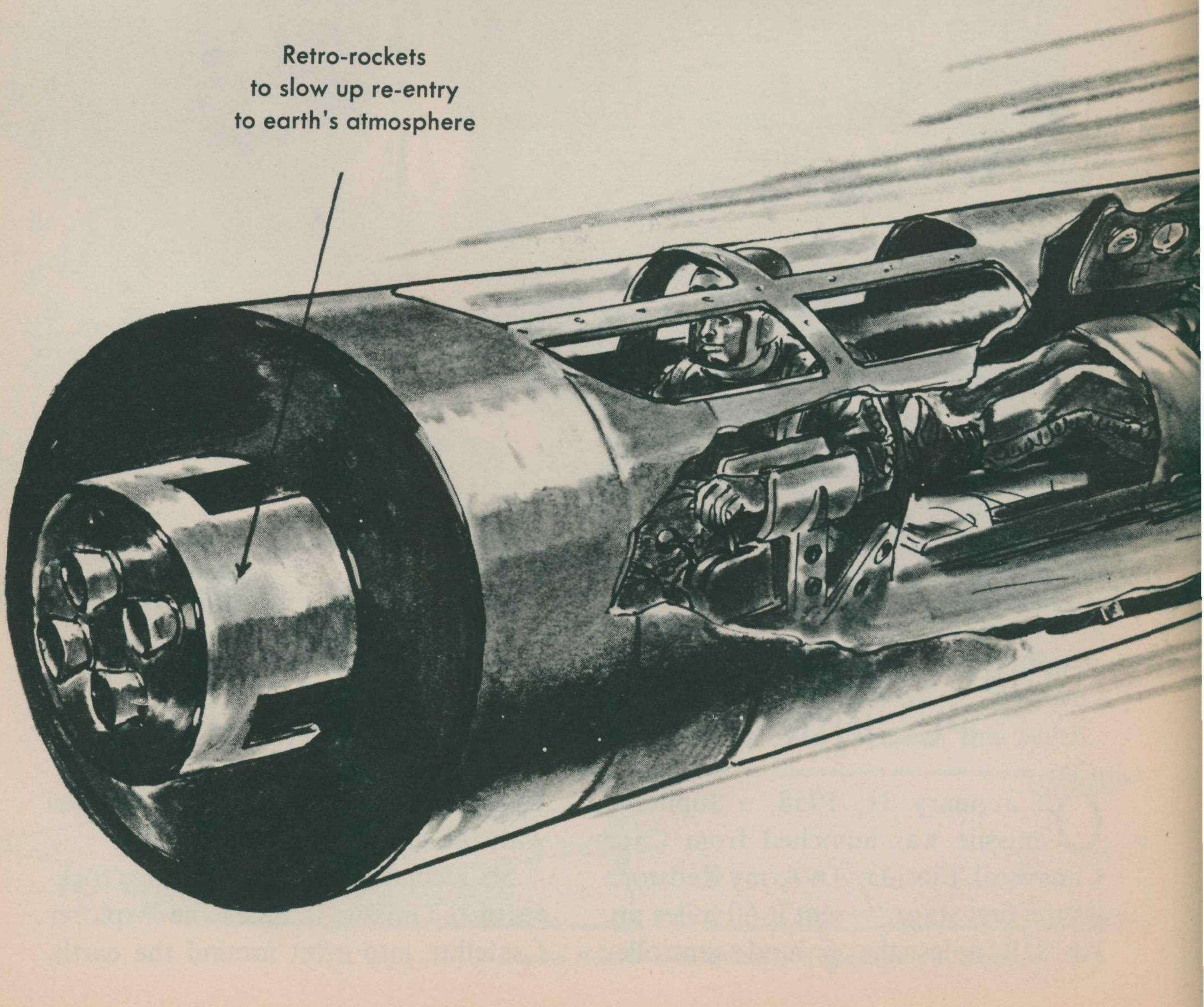
Six seconds later the third-stage rockets of the missile rammed the Explorer I satellite into orbit around the earth.

WHAT WAS PROJECT MERCURY?

AMERICA'S PROJECT MERCURY had three objectives: to study man's ability to travel in space; to place manned satellites in orbit around the earth; and to return the pilot and his space capsule safely to earth.

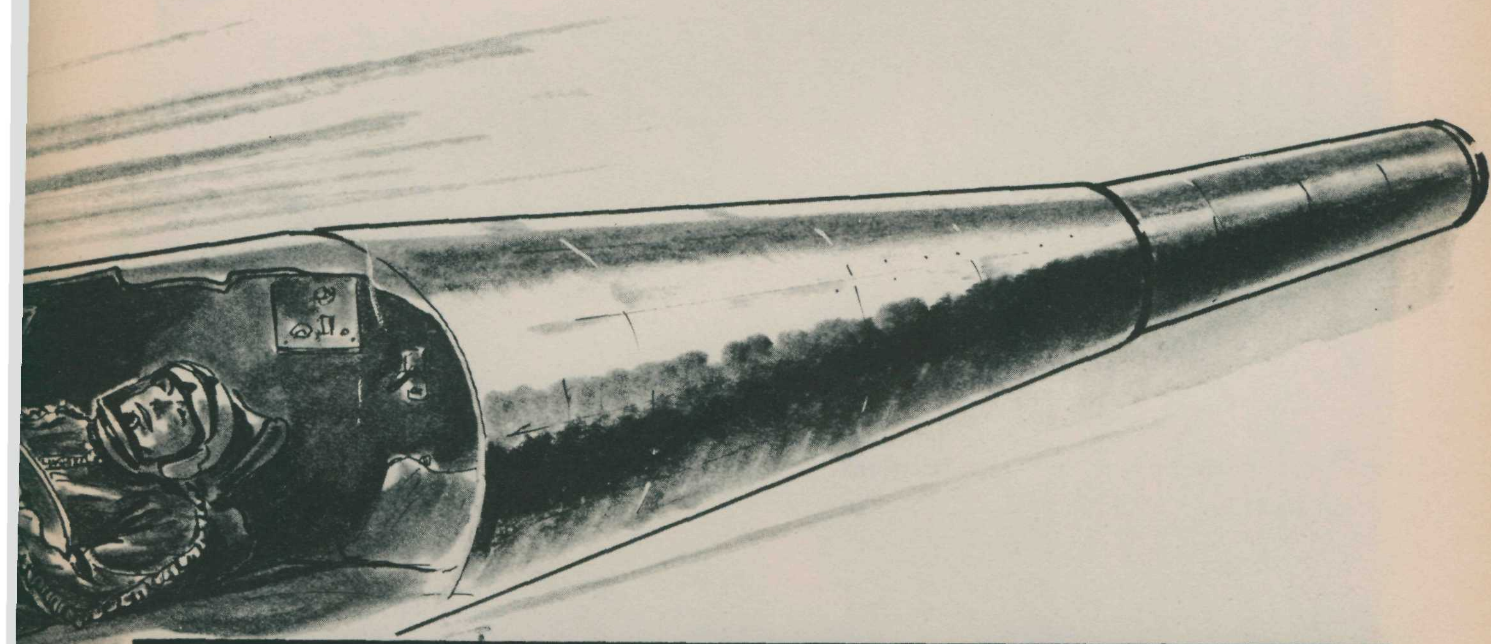
On May 5, 1961, Navy Commander Alan B. Shepard, Jr., America's first astronaut, was launched into space in the Mercury capsule *Freedom 7* for a 15-minute, 115-mile-high suborbital flight. Another suborbital flight was made in *Liberty Bell 7* by Marine Captain Virgil I. Grissom. Then there fol-

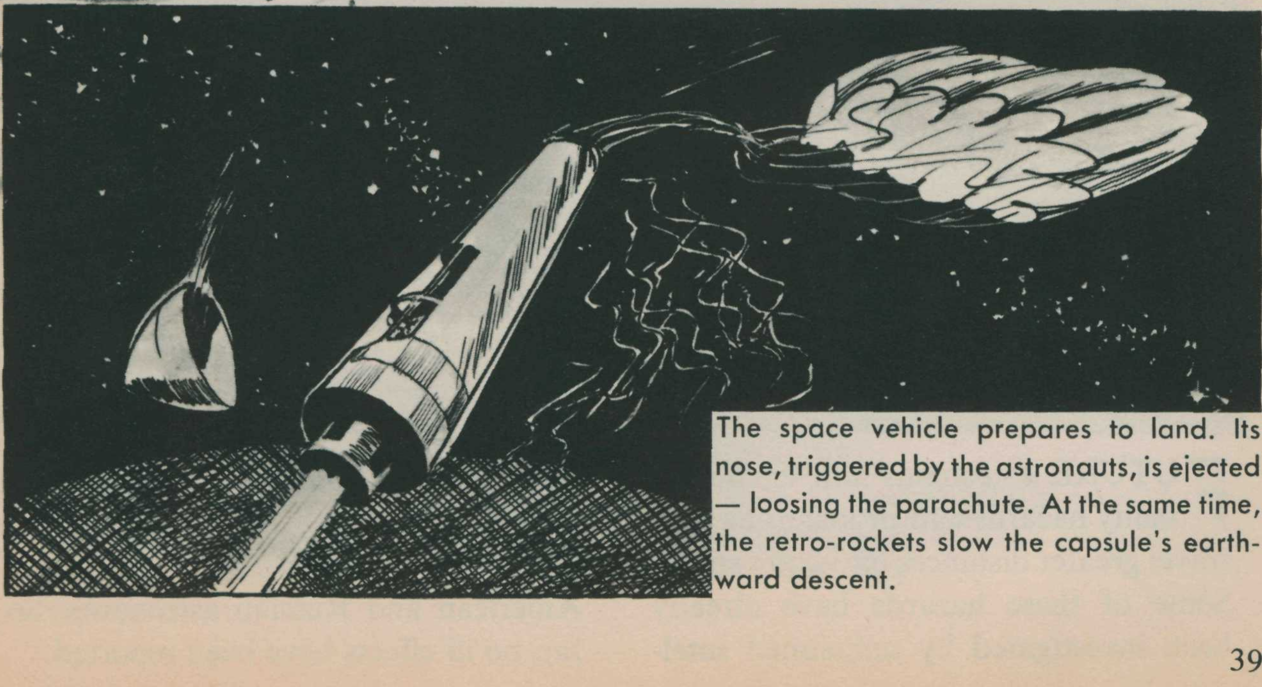
Artist's conception, cutaway view, of a space capsule of a type to follow *Project Mercury*. This larger capsule carries two astronauts.



lowed four orbital flights by Project Mercury astronauts, Marine Lt. Colonel John Glenn in *Friendship 7,* Lt. Commander M. Scott Carpenter in *Aurora 7,* Commander Walter M. Schirra, Jr. in *Sigma 7,* and finally Air Force Colonel L. Gordon Cooper, Jr. in *Faith 7.* Colonel Cooper orbited the earth 22 times in 34½ hours and traveled more than half a million miles.

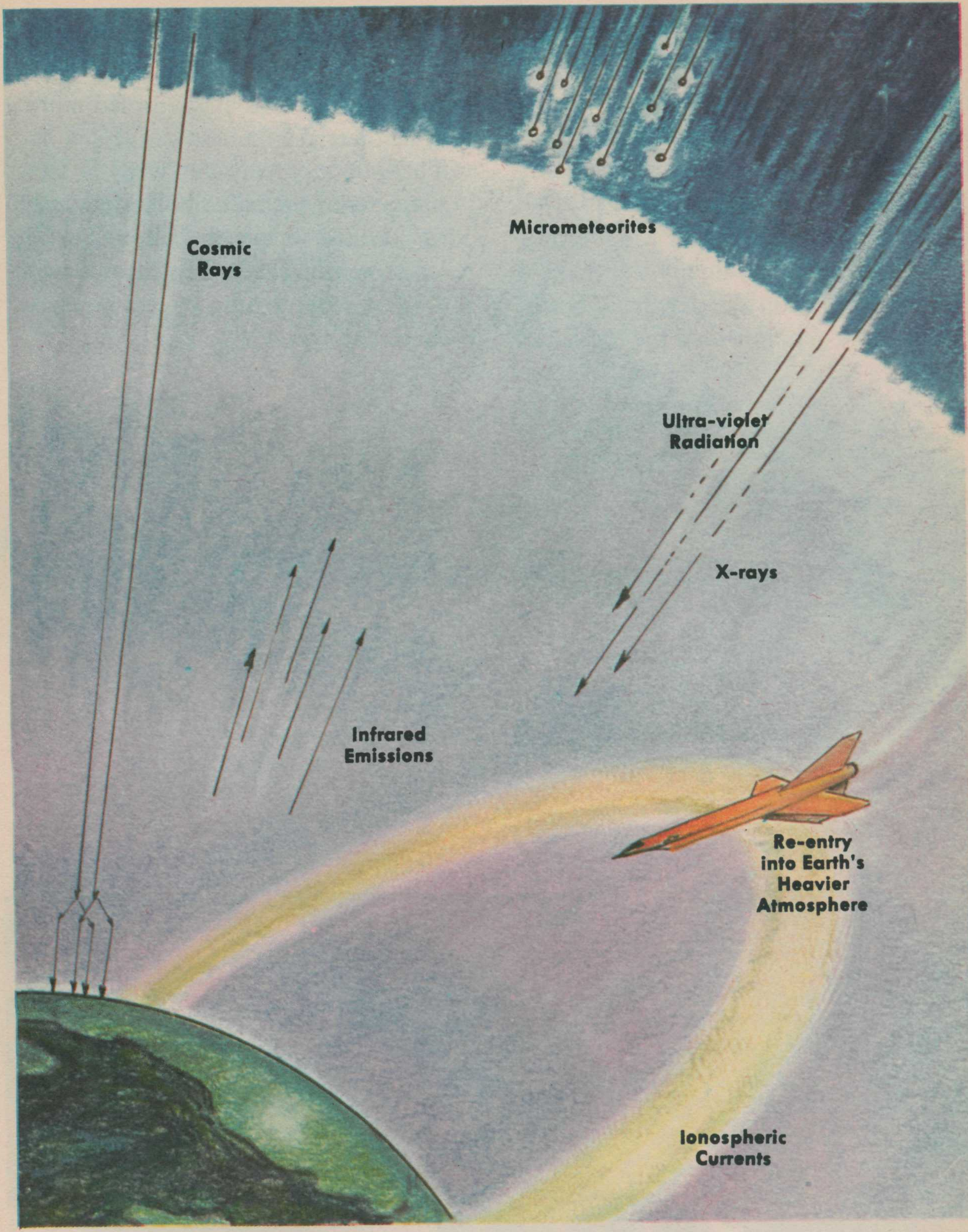
The Mercury capsules were 7 feet in diameter at the base and 10 feet tall. They orbited between 100 and 150 miles above the earth. The capsule was slowed at reentry time by firing retro-rockets.





The space vehicle prepares to land. Its nose, triggered by the astronauts, is ejected — loosing the parachute. At the same time, the retro-rockets slow the capsule's earthward descent.

WHAT DANGERS DOES MAN FACE IN OUTER SPACE?

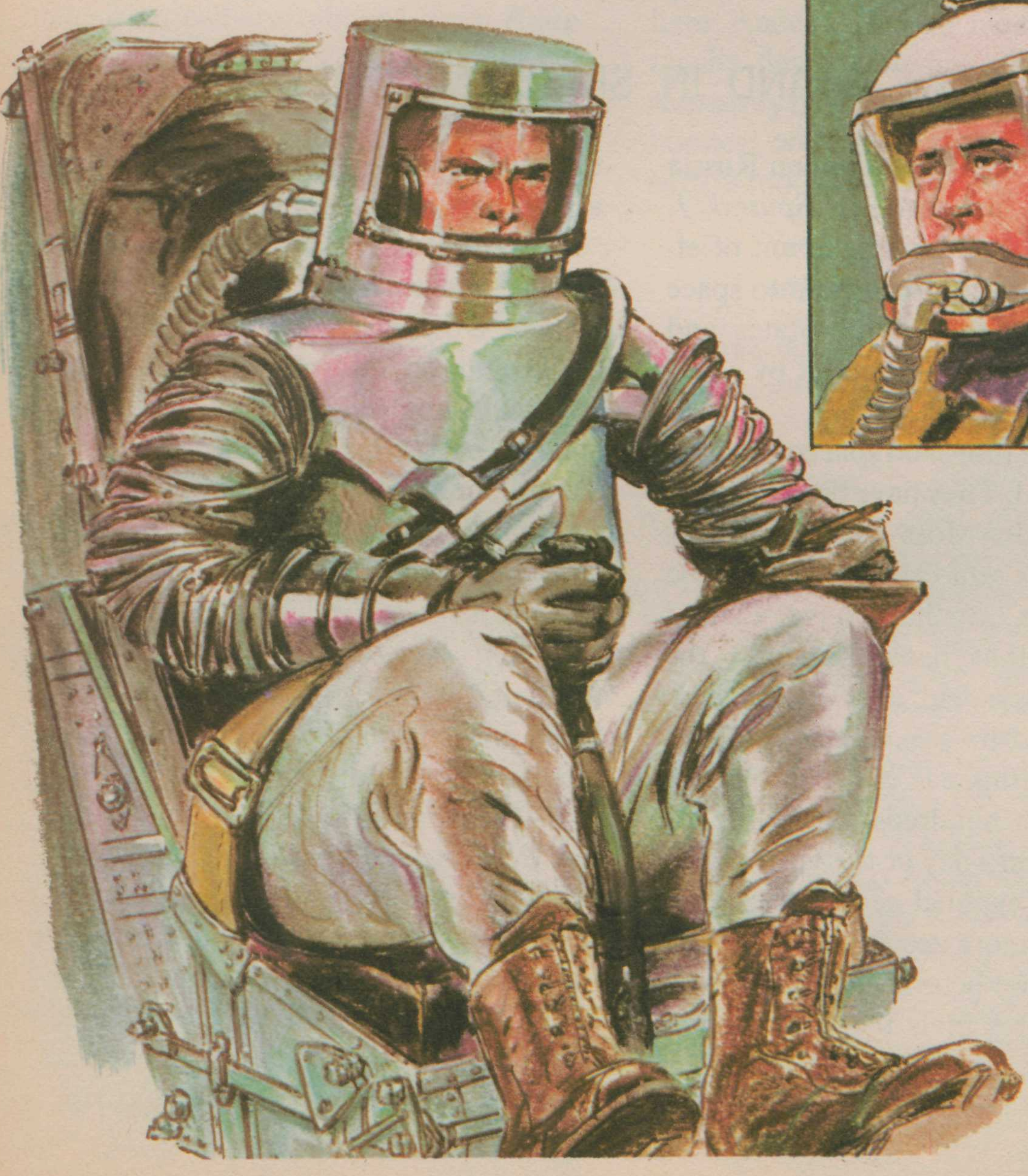


FUTURE astronauts will encounter many hazards and problems as they travel greater distances into outer space. Some of these hazards have already been investigated by unmanned satellites that have radioed back important information. Some of these hazards have already been investigated by American and Russian astronauts. So far, no ill effects have been reported.

HOW MUST MAN BE PROTECTED IN SPACE VEHICLES?

DURING journeys into space, humans must carry with them a sufficient supply of oxygen, food and liquid to last until their return to earth. They must also be protected against searing heat, bitter cold, and shielded against intense radiation known to exist in bands around the earth. Man must be held in place during rapid acceleration and brutal deceleration while leaving and returning to our atmosphere. Once in space, he must learn to cope with the problems of weightlessness and periods of complete inactivity.

THE AIR FORCE MA-I HELMET FOR OUTER SPACE



HOW CAN MAN'S SAFE RETURN TO THE EARTH'S ATMOSPHERE BE SOLVED?

RETURNING to earth from space is as great a problem as leaving for space. For many years, scientists have worked to overcome the difficulties of re-entry.

When a space ship, traveling at thousands of miles an hour, descends toward earth, the atmosphere creates enough friction to melt the ship's metal hull. Special metals and special insulating materials have been developed to overcome the hazards of re-entry, enabling the American and Russian astronauts to return safely.

The *Project Mercury* capsule has a special surface, some of which burns away, thereby protecting the metal beneath. When the returning ship is close to the earth's surface, a parachute opens to slow its descent to landing speed.

WHERE DO WE STAND IN SPACE ACCOMPLISHMENTS?

The Space Age opened when Russia launched the first satellite, *Sputnik I.* Since then a bewildering amount of effort and money has been put into space exploration by the United States and Russia, and a smaller amount by a few other nations.

Well over a thousand spacecraft have been launched. They have been of many different kinds. Most have been artificial satellites sent orbiting around the earth. These satellites have carried instruments that have measured the earth's magnetic field, its radiation field, its shape, and its size. Other satellites have photographed clouds, sending back to earth hundreds and hundreds of pictures every day of the year. These photos have enabled scientists to predict weather more accurately than they ever have done before. Other satellites have sent out signals that help ocean-going vessels navigate more precisely. Still other satellites have measured the tiny meteors that bombard the earth's atmosphere by the billions every day.

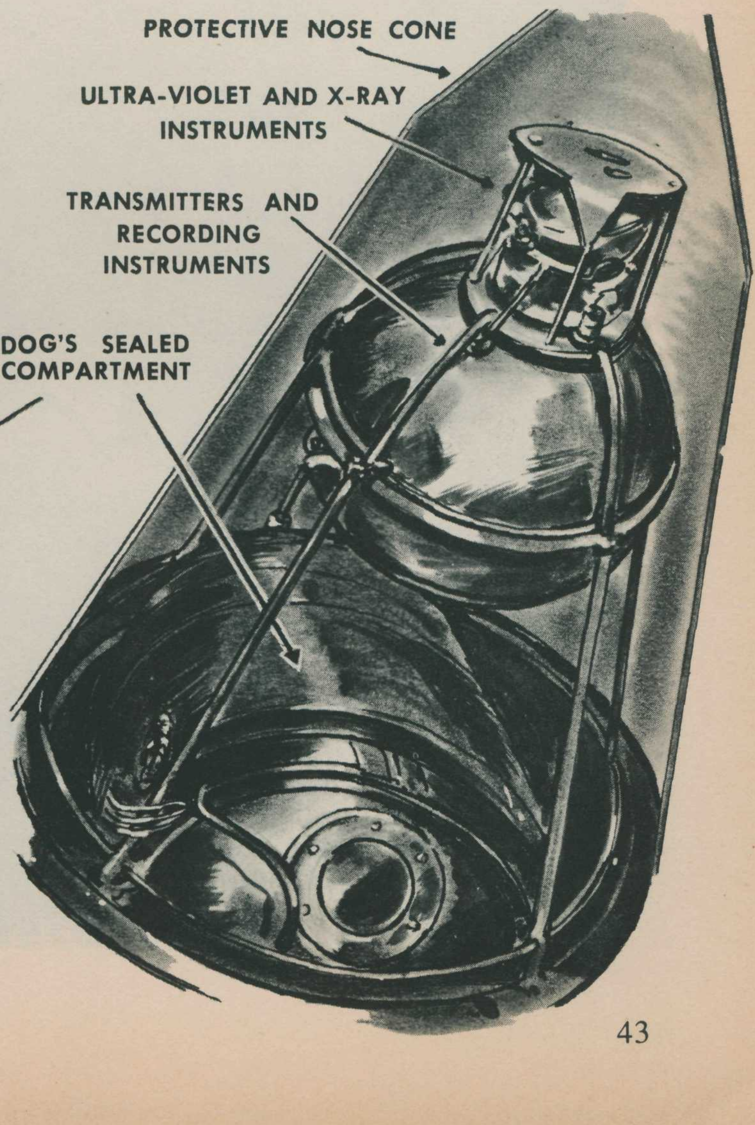
Spacecraft have gone to the moon, to Venus, and to Mars to explore these planets. Others have journeyed close to the sun to get information about that huge astronomical body. The United States sent *Mariner II* on a mission to Venus, our nearest neighbor in the solar system, and learned that it is too hot for living things as we know them on earth to exist there. The United States also sent *Mariner IV* to photograph Mars and learned that Mars has a surface pocked with craters, like the moon's surface.

In 1967, both the United States and the U.S.S.R. sent space probes to the planet Venus which revealed that its surface is too hot — more than 500°F. — to support life as we know it. The U. S. probe *Mariner II* had found, back in 1962, that Venus rotates in a direction opposite to that of the earth.

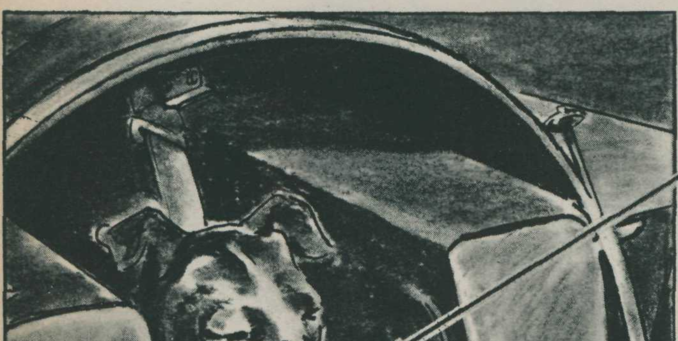
One rotation takes 225 earth days. The long Venusian day, equal to more than 100 earth days, allows the surface of Venus to become very hot, and Venus' thick atmosphere of carbon dioxide holds in the heat. It will be a long time before men find a way to explore Venus.

The moon has been explored by unmanned spacecraft. In 1959, Russia's *Lunik III* photographed the far side of the moon. In 1964 and 1965, the United States made more than 17,000 close-up photographs of the moon with television cameras aboard three *Rangers*. Russia soft-landed a camera on the moon in early 1966 and the United States followed with similar feats, the *Surveyor* space probes. The United States thoroughly mapped the lunar surface by means of television cameras called *Lunar Orbiters*. All this photography had one main purpose — to help scientists find a suitable landing site on the moon for astronauts.

The astronauts themselves trained at space voyaging in *Project Mercury* and *Project Gemini*. Then, in late 1968, the greatest achievement in manned space flight so far was made by the United States. This was the moon-orbiting voyage of the three *Apollo 8* astronauts, Frank Borman, James Lovell, and William Anders. Having made this technically flawless voyage, man is just a step away from setting foot on an astronomical body other than the earth, the earth's moon.



One of the first living space travellers was a dog; it was a passenger in a Russian spacecraft, Sputnik II (October, 1957).

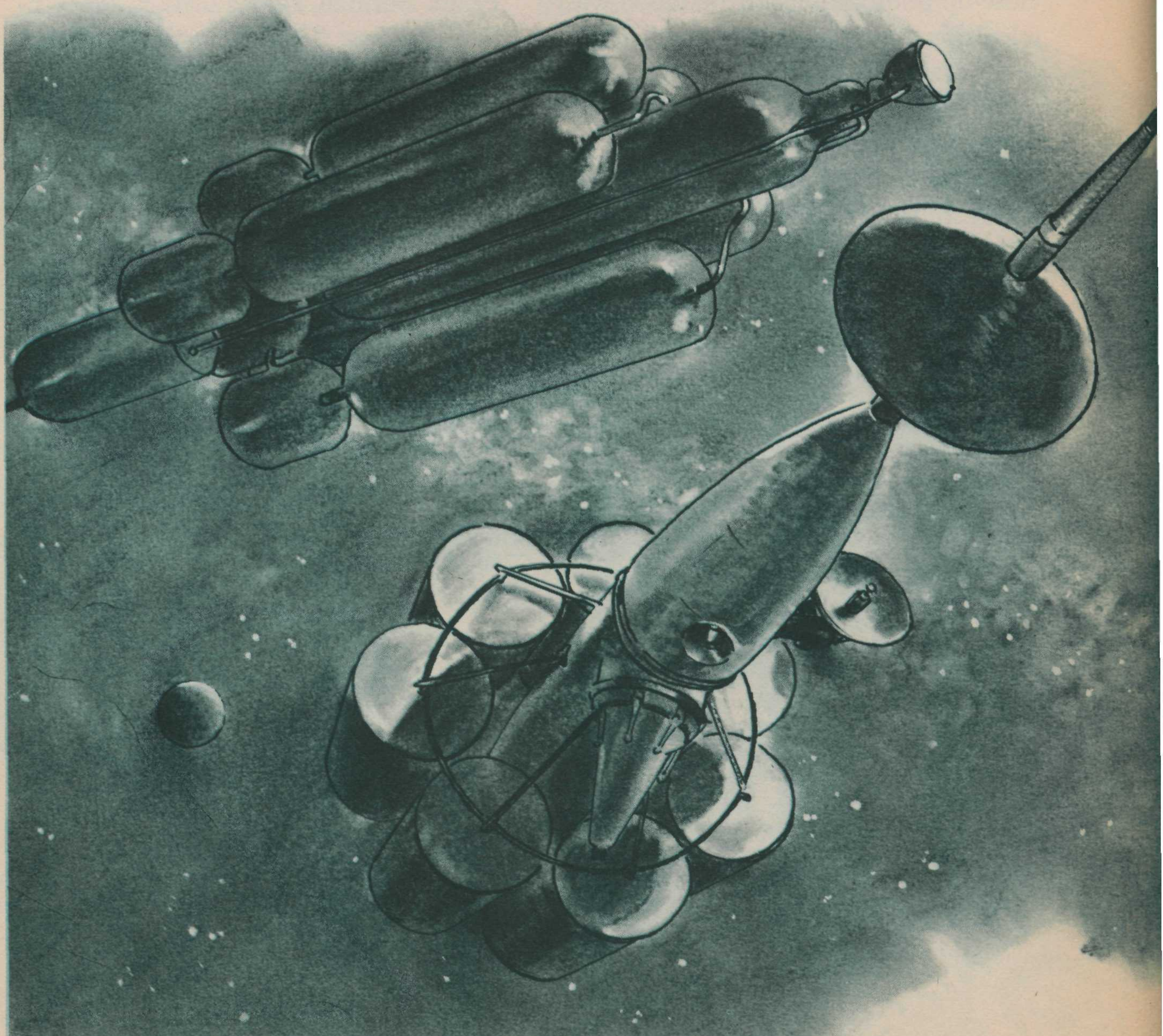


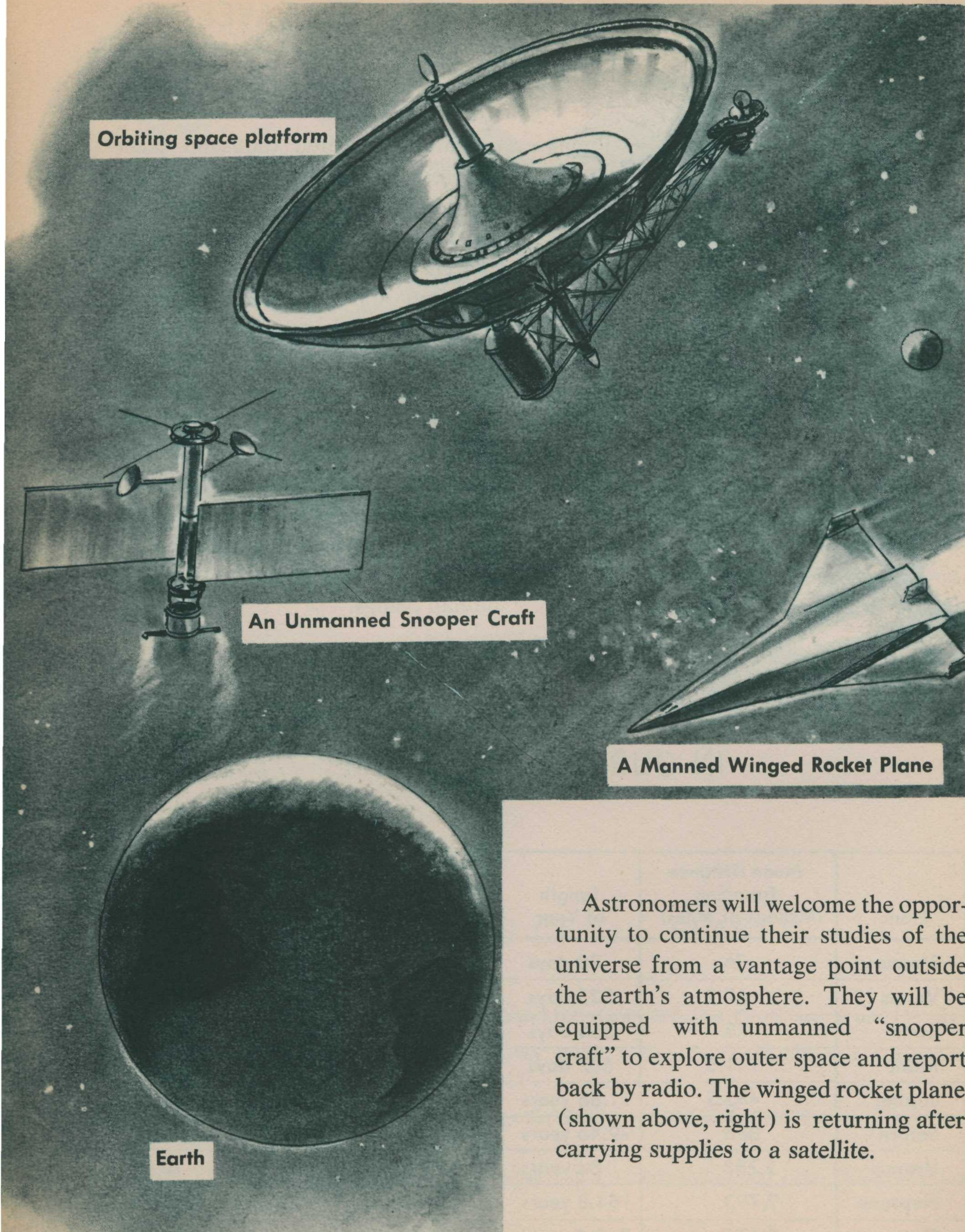
HOW DOES MAN EXPECT TO LIVE IN OUTER SPACE?

SPACE scientists have placed into orbit around the earth permanent satellites used as relay stations for radio and television broadcasts. These are called communications satellites. Other long-term satellites observe the weather and aid navigation.

Various types of space stations for different uses will be lofted into orbit in separate sections and assembled by workmen in space suits. At regular intervals the satellites will be restocked with provisions, fuel and relief crews sent up from the earth.

Interplanetary Space Stations





Astronomers will welcome the opportunity to continue their studies of the universe from a vantage point outside the earth's atmosphere. They will be equipped with unmanned "snooper craft" to explore outer space and report back by radio. The winged rocket plane (shown above, right) is returning after carrying supplies to a satellite.

WHERE CAN MAN GO WHEN HE LEAVES THE EARTH?

THE EARTH is a small planet among billions of stars and other celestial bodies in a universe that extends beyond man's imagination. A true star is any heavenly body like our sun, which is self-luminous; planets and satellites shine by reflected light. The solar system to which the earth belongs is made up of nine planets which revolve around the sun. Satellites, like the moon which orbits around the earth, circle around the planets. Our solar system is only a tiny part of a larger galaxy of stars — the Milky Way — and astronomers have discovered about a hundred million such galaxies, each of which may contain a hundred thousand planets.

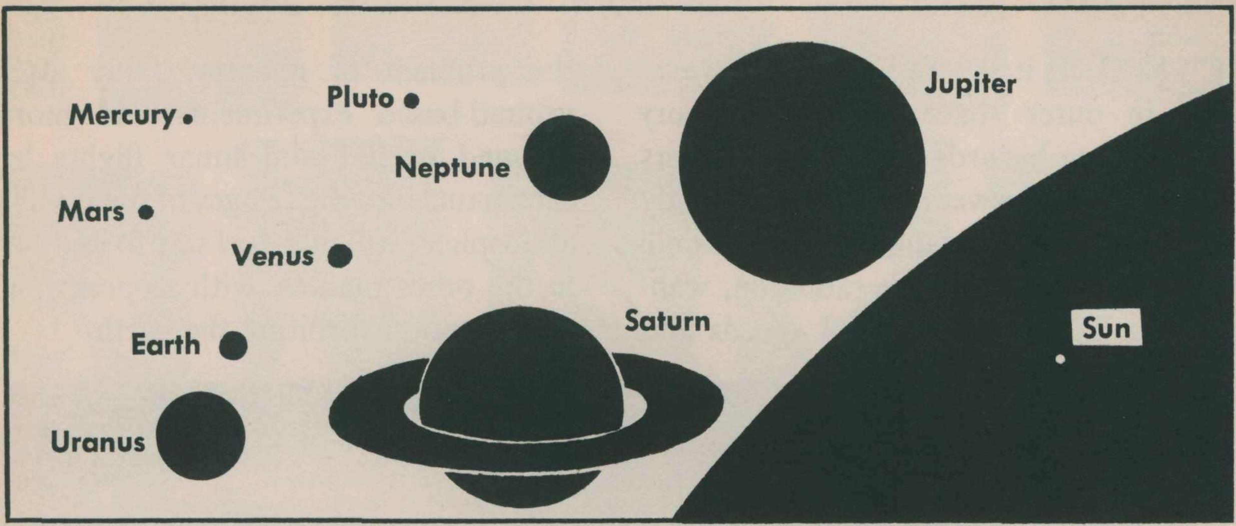
It seems likely that somewhere among these billions of heavenly bodies, living conditions suitable to man may be present. He has thrived on earth because of a combination of elements: a deep band of atmosphere, water to drink, and heat for warmth and cooking.

Among the planets and satellites of our solar system, many are too hot or too cold to support human life, while others give off chemical fumes that would destroy it. Astronomers believe that of all the planets in our solar system, only Mars might be livable for human beings.

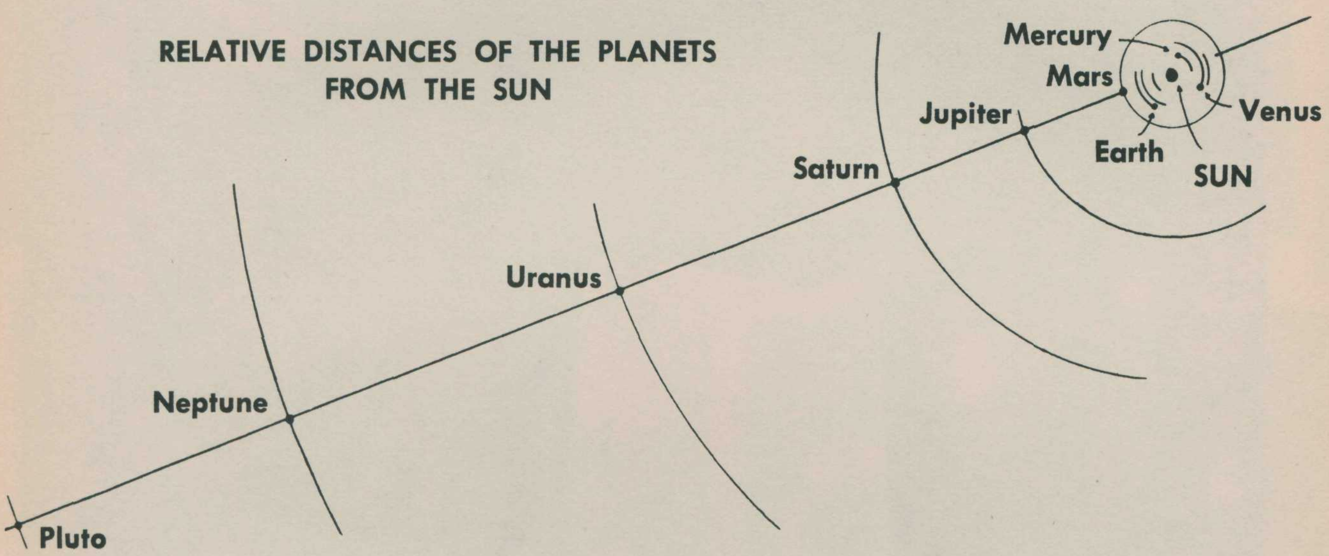
HOW FAR AWAY ARE OTHER PLANETS IN OUR SOLAR SYSTEM?

Planet	Mean Distance from Sun (Millions of Miles)	Length of Year	Period of Rotation	Diameter (Miles)	Gravity at Surface (Earth=1)
Mercury	36	88 days	88 days	3,000	0.27
Venus	67.2	225 days	Unknown	7,600	0.85
Earth	93	365 days	1 day	7,920	1.00
Mars	141.5	687 days	24.6 hours	4,220	0.38
Jupiter	483.3	11.86 years	9.9 hours	89,000	2.64
Saturn	886	29.46 years	10.2 hours	75,000	1.17
Uranus	1,783	84 years	10.7 hours	31,000	0.92
Neptune	2,793	164.8 years	15.8 hours	28,000	1.12
Pluto	3,675	248.4 years	Unknown	6,300	Unknown

RELATIVE SIZES OF THE PLANETS



RELATIVE DISTANCES OF THE PLANETS FROM THE SUN



THE SATELLITES OF THE PLANETS

MARS: 2 satellites. Diameters: 5 and 1 miles. Orbits: 3,700 and 14,500 miles. Circuit time: ½ and 1½ days.

JUPITER: 12 satellites. Diameters: 20 to 3,200 miles. Orbits: 112,600 to 14,888,000 miles. Circuit time: ½ to 760 days.

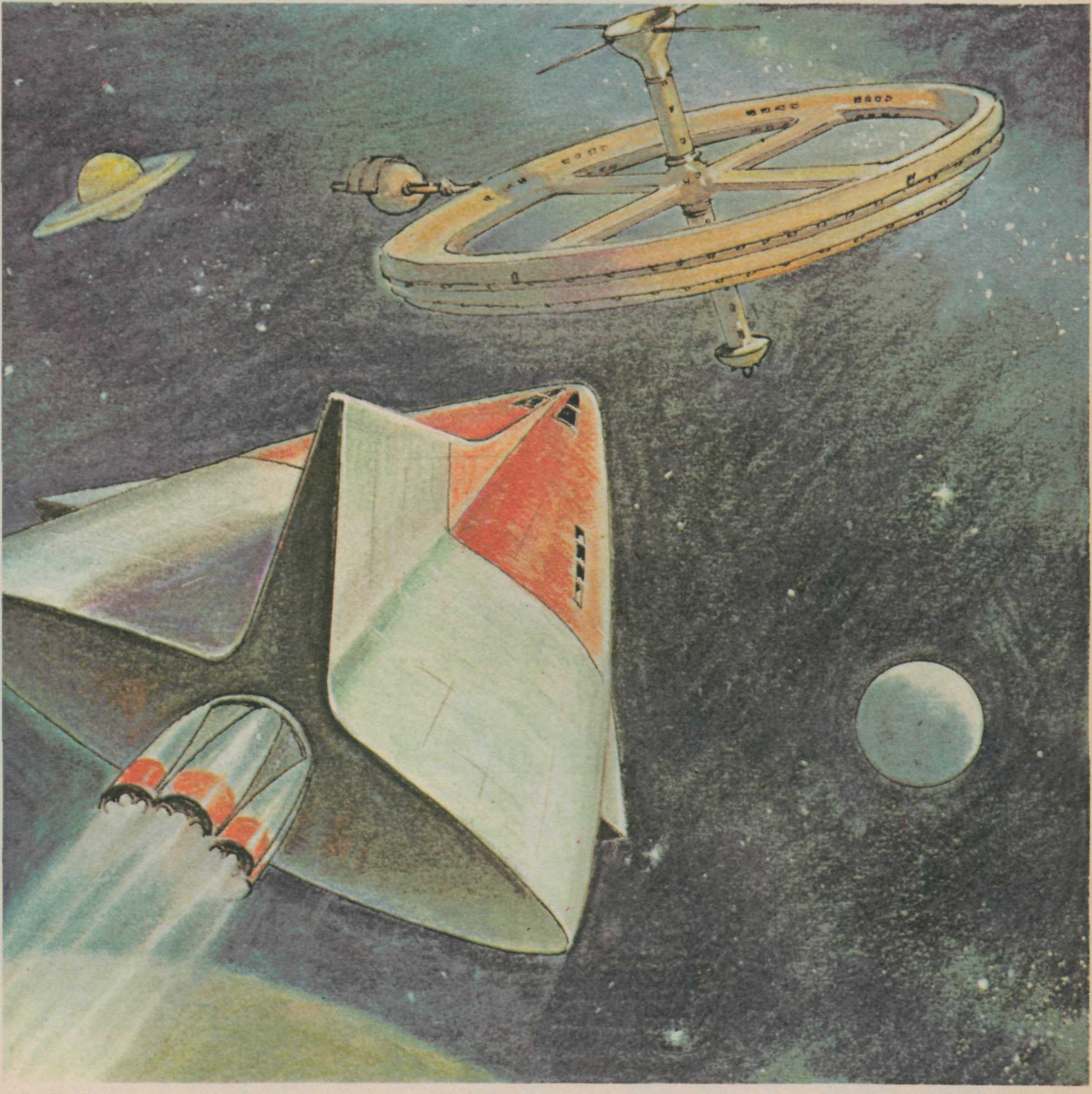
SATURN: 9 satellites. Diameters: 200 to 3,550 miles. Orbits: 115,000 to 8,034,000 miles. Circuit time: 1 to 550 days.

URANUS: 5 satellites. Diameters: 150 to 1,000 miles. Orbits: 80,800 to 364,000 miles. Circuit time: 1½ to 13½ days.

NEPTUNE: 2 satellites. Diameters: 200 and 3,000 miles. Orbits: 220,000 and 5,000,000 miles. Circuit time: 6 and 730 days.

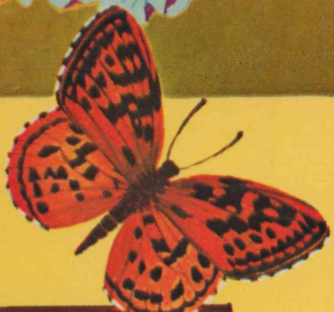
WHEN WILL TRUE SPACE TRAVEL BEGIN?

BEFORE it is safe for man to travel in outer space, there are many frightening hazards for which scientists must find answers. Experts already know about the dangers from cosmic rays, a band of intense radiation, wandering meteorites, blast-off speeds and the problem of re-entry. Only after ground-based experiments and more manned orbital and lunar flights by astronauts into the fringes of the earth's atmosphere will man feel safe to journey to the other planets, with stopovers at space stations orbiting the earth.



In the future, manned space stations orbiting around the earth may be visited regularly by shuttle-craft with supplies and men.

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5039 ROBOTS AND ELECTRONIC BRAINS
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5042 THE AMERICAN REVOLUTION
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5045 TIME
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5047 GUNS
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5050 OLD TESTAMENT
5051 BUILDING
5053 TREES
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5055 NORTH AMERICAN INDIANS
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5057 THE POLAR REGIONS
5058 COINS AND CURRENCY
5059 BASIC INVENTIONS
5060 THE FIRST WORLD WAR
5061 ELECTRONICS
5062 DESERTS
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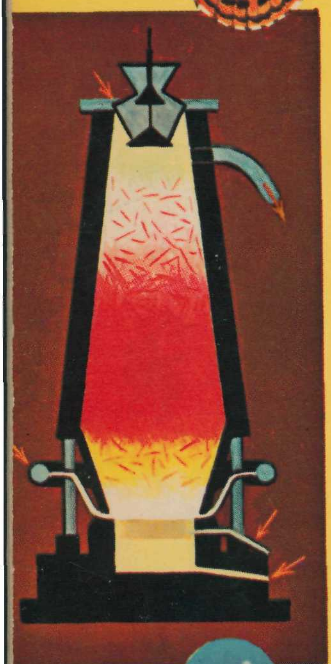

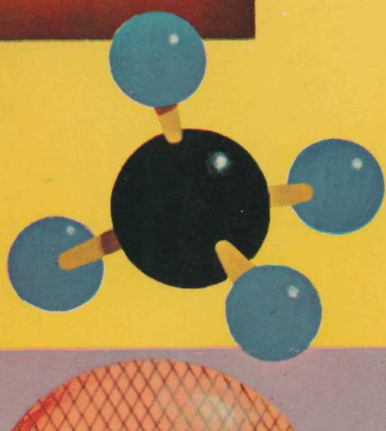


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